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AUSTRALIAN SKY & TELESCOPE

THE ESSENTIAL MAGAZINE OF ASTRONOMY

ISSUE 87

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First pictures from New Horizons' historic encounter with Pluto and its retinue of moons. See page 12.

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The final new world

As I write this, two days after New Horizons' historic fly-by of the Pluto system, I can't help but feel a sense of sadness mixed in with all of the exhilaration and wonder. For this will almost certainly have been the last exploration of a major Solar System body in my lifetime. Why? Well, for a start, we know that there are no more planets within the orbit of Neptune. Sure, there are thousands of Kuiper Belt Objects further out, but they're all probably pretty much like Pluto. If there's another large body out there to be discovered, it's going to be much farther out — and astronomers have good reason to think it would have to be at least three times Pluto's distance from the Sun.

But let's say that one was found tomorrow, and a mission proposed. It'd take at least 5-6 years to design, build and launch it, and — given that it took New Horizons almost 10 years to reach Pluto — it would take a good 30-odd years for the spacecraft to reach the new world. So that's already 35 years, and assumes that a new planet is found tomorrow. It won't be. It might be decades before one is discovered and a mission approved. So conservatively, we're looking at 50 years at the very least before we visit another major world for the very first time... assuming one exists.

But all that aside, I feel so fortunate to have lived during the initial era of space exploration, and the first reconnaissance of the Solar System. And it's certainly not over — the Juno mission will arrive at Jupiter next year, there are more Mars missions in the works, the James Webb Space Telescope is soon to launch, and there are plenty of other places to visit and explore. The years ahead will not be dull, that's for sure.

Jonathan Nally
Editor

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EDITORIAL
EDITOR Jonathan Nally
ART DIRECTOR Simone Marinkovic
CONTRIBUTING EDITORS
John Drummond, David Ellyard,
Ross Gould, Steve Kerr,
Alan Plummer, David Seargent
EMAIL info@skyandtelescope.com.au

ADVERTISING
ADVERTISING MANAGER Jonathan Nally
EMAIL jonathan@skyandtelescope.com.au

SUBSCRIPTION SERVICES
TEL 02 9439 1955
EMAIL subs@paragonmedia.com.au

PARAGON MEDIA PTY LIMITED
ABN 49 097 087 860
TEL 02 9439 1955
FAX 02 9439 1977
ADDRESS Suite 15, Level 2/174 Willoughby
Road, Crows Nest NSW 2065 PO Box 81, St
Leonards, NSW, 1590

PUBLISHER
Ian Brooks



PARAGON Media Pty Limited

SKY & TELESCOPE INTERNATIONAL

EDITOR IN CHIEF
Peter Tyson

EDITORIAL
SENIOR EDITOR

Alan M. MacRobert
EQUIPMENT EDITOR Sean Walker
SCIENCE EDITOR Camille M. Carlisle
WEB EDITOR Monica Young
OBSERVING EDITOR Susan N.
Johnson-Roehr

SENIOR CONTRIBUTING EDITORS
J. Kelly Beatty, Robert Naeye, Roger
W. Sinnott

DESIGN DIRECTOR Patricia Gillis-
Coppola

ILLUSTRATION DIRECTOR Gregg
Dinderman

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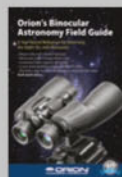
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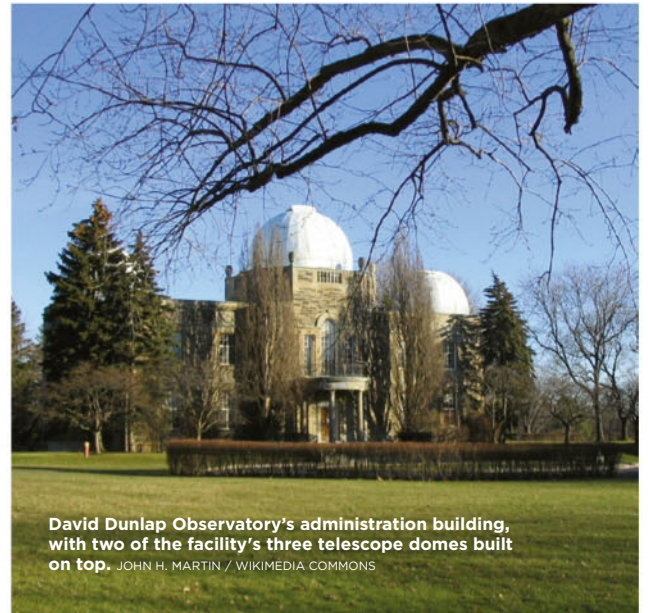
Amateurs get keys to David Dunlap Observatory

On April 15, the Royal Astronomical Society of Canada (RASC) announced that its 900-member Toronto Centre is taking ownership of the historic David Dunlap Observatory, located in the suburb of Richmond Hill. The observatory and its administrative building are being donated by Corsica Development, which purchased the facility and 77 hectares of land around it for US\$70 million from the University of Toronto in 2009. That's when local RASC volunteers, who had been involved in the observatory's outreach programs for decades, stepped in to maintain and operate the historic facility. Since then all parties involved have been working amicably toward this final arrangement. Corsica is also giving 40 acres of the property

to the town, which will keep it from being developed.

The observatory got its start in 1935 after the widow of David Alexander Dunlap, a wealthy mining executive and astronomy enthusiast, provided the funds for construction. Its premier instrument, a 1.9-metre reflector, was then the second largest in the world and remains the largest telescope in Canada. But urban growth long ago made the site unsuitable for most types of observational research, and the university's astronomical interests shifted to larger facilities elsewhere. Dunlap is just one of several observatories around the world adapting to changing management or financial circumstances.

■ J. KELLY BEATTY



David Dunlap Observatory's administration building, with two of the facility's three telescope domes built on top. JOHN H. MARTIN / WIKIMEDIA COMMONS

DARK MATTER | How slippery is dark matter?

In their effort to understand the unseen matter that holds spinning galaxies together and forms the skeleton of cosmic structure, astronomers are trying to determine how much this dark matter interacts with itself. The answer seems to be: not much.

Weakly interacting massive particles (WIMPs), physicists' most popular dark particle candidate, are downright antisocial — they glide right past one another.

But in simulations, slippery dark matter particles pool too easily, creating deep gravitational wells in which galaxies crowd more densely than observed out in the real universe.

One way to overcome the pooling problem is to make dark matter less slippery. In alternative models, so-called 'hidden-sector' dark matter particles make contact, explains Jonathan Feng (University of California, Irvine). Many of these models have the added benefit of explaining a mysterious X-ray spectral line seen in some galaxies and galaxy clusters.

Perfectly slippery dark particles should have a self-interaction cross section (a measure of how strongly they interact) near $0 \text{ cm}^2/\text{g}$. Hidden-sector models propose

values that range from 0.1 to $10 \text{ cm}^2/\text{g}$.

Astronomers can indirectly measure dark matter's stickiness by looking at galaxy cluster collisions. When clusters collide, most galaxies sweep right past one another, but their tenuous gas halos crash together and produce beautiful, complex X-ray emission.

If it's slippery, dark matter will stay closely aligned with the galaxies. (The dark matter isn't seen directly but by its gravitational distortion of background light.) But if dark matter particles interact with one another, then they'll do one of two things: the dark mass will slow down, lagging behind the galaxies' motion, or the dark particles will scatter, displacing the dark mass from the galaxies. Either would change the distortion pattern.

Previous observations have limited the cross section to less than $1.25 \text{ cm}^2/\text{g}$. Narrowing the possibilities further has proven a challenge, mostly because it is difficult to understand individual systems' 3D geometries.

But now David Harvey (Observatoire de Sauverny, Switzerland) and colleagues have taken a statistical approach, averaging out the measurements of 30 galaxy clusters to

do away with any 3D uncertainty. Drawing from the archives of the Hubble Space Telescope and Chandra X-ray Observatory, the team measured the offset between the galaxies and the dark mass. The astronomers found that, across 30 clusters, the offset was essentially zero. Dark matter must be slippery indeed, with a cross section less than $0.47 \text{ cm}^2/\text{g}$, the team reports in the March 27 issue of *Science*.

The analysis is excellent, but there are limitations, says Douglas Clowe (Ohio University). For one, it's all archival data, collected for disparate science goals. To level the playing field, the team opted to limit the analysis to observations through one filter. But that makes it difficult to separate cluster galaxies from foreground and background galaxies.

Even with the tighter limit from Harvey's study, hidden-sector models have enough wiggle room to remain viable. "The really interesting message here," Feng says, "is that these observations are getting tighter and tighter in a very interesting region of parameter space."

■ MONICA YOUNG

GALACTIC CENTER

Mysterious X-rays spotted in Milky Way

NASA's NuSTAR mission has detected an unexpected haze of high-energy X-rays in our galaxy's crowded centre. Kerstin Perez (Columbia University) and colleagues found the X-rays emanating from within our galaxy's central 10 light-years or so, they report in the April 30 issue of *Nature*. In and of themselves, X-rays from the galactic centre aren't unusual. But the X-rays NuSTAR detects don't seem to be associated with structures already known to exist, such as the supernova remnant Sgr A East or the dust and gas clouds of Sgr A West that are falling toward the supermassive black hole.

Instead, the team proposes that thousands of dead stars could be responsible for the high-energy X-rays: massive (and still-growing) white dwarfs, spun-up pulsars, or black holes and neutrons stars feeding on low-mass companion stars. But each of the proposed explanations has its own set of challenges, and astronomers don't know which is correct.

Take millisecond pulsars, potentially the best option. These neutron stars flash energetic beams in our direction as they spin like blindingly quick lighthouses. They began as the cores of massive stars that went supernova, then spun themselves up with gas stolen from companion stars. Many massive stars die in the galactic centre, so these pulsars' existence seems inevitable. Such a population might even help explain a mysterious excess of gamma rays seen from this region.

But although astronomers expect to see lots of millisecond pulsars in the galactic centre, so far they've spotted none. That might be because the gas and dust between the galactic centre and us smears out the pulsing radio signals. But millisecond pulsars' hot surfaces also emit low-energy X-rays, so if there were a large number of these pulsars, then other X-ray telescopes such as NASA's Chandra X-ray Observatory should have spotted them. They haven't.

■ MONICA YOUNG

SUN | Do explosions heat the Sun's corona?

New evidence suggests that nanoflares, small but potent bursts of energy, might heat the Sun's outer atmosphere. But the evidence is still up for debate.

For decades, scientists have struggled to understand why the Sun's outer atmosphere, known as the corona, is a blistering-hot few million degrees when its visible 'surface,' the photosphere, bubbles away far below at only thousands of degrees. Ideas range from waves rippling along magnetic field lines to field lines twisted so tightly they snap, releasing tremendous amounts of energy.

There's also another question to answer: is the heating process steady, or does it occur in explosive bursts?

These bursts would be small stuff — they release only a billionth the energy of regular flares, and they'd be too small, quick and faint for telescopes to capture individually. But even a nanoflare would be equivalent to a 50-megatonne hydrogen bomb, and millions going off per second could feasibly heat the corona.

Now astronomers have found indirect evidence that these small explosions heat the solar corona. On April 28 Adrian Daw (NASA Goddard) presented results from

the Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS) sounding rocket mission at the first Triennial Earth-Sun Summit. The EUNIS results point to short-lived pockets of superhot plasma that are about 10 million Celsius, ten times hotter than the sizzling corona around them. The researchers argue that these temperatures could only come from the combined echo of many tiny flashes in the solar atmosphere.

But if nanoflares behave like mini versions of larger, well-observed flares (and we don't know whether that's true), then the energy they unleash ought to accelerate particles, which will emit a particular pattern of X-rays. Observations with NASA's NuSTAR spacecraft reveal X-ray emission from the super-hot gas, but the telescope sees no sign of the particle signature needed to cinch the case.

That might be because the Sun is still too active, overwhelming NuSTAR's vision. As solar activity decreases, NuSTAR will have a better shot at making out fainter, non-thermal emission — and perhaps providing definitive evidence for nanoflares.

■ MONICA YOUNG

GALAXIES

Runaway compact galaxies?

Astronomers have discovered 195 compact elliptical galaxies, upping the known number of these weird objects sixfold. These dwarf galaxies are puny balls of old stars, each having maybe a few billion solar masses. Most come in clusters, and observers have found debris around some, suggesting that they were once larger but had their outer edges ripped from them by other galaxies. But a couple sulk all by themselves, making the tidal disruption theory problematic: if there's nothing around to strip material off these galaxies, did they really shrink?

In the April 24 issue of *Science*, Igor Chilingarian (Smithsonian Astrophysical Observatory) and Ivan Zolotukhin (Moscow State University, Russia) report their discovery of 195 of these objects, with 56 in clusters, 128 in galaxy groups and 11 in

isolation. Given the galaxies' motions and sizes, the authors suggest that interactions with two or more other galaxies could sling these diminutive ellipticals into the cosmic outback. That would explain how galaxies created via tidal disruption sit out in the sticks, where there aren't many galaxies to interact with.

But astronomers need to check this theory with rigorous computer simulations — it's by no means conclusive. Other researchers have suggested that isolated compact ellipticals might arise when dwarf galaxies merge. With no additional stuff nearby to feed on, the compact ellipticals would simply stop growing and never reach full size. This new, larger population will thus help astronomers explore these galaxies' origin. ♦

■ CAMILLE M. CARLISLE



Mars and the meteorite

The continuing quest to find life on the Red Planet



The desolate red plains of Mars are not where you'd expect to find life today.. but what about in the past? NASA

Is there, or has there ever been, life on Mars? The question has been posed many times over the centuries. Many a science fiction story has been built on the premise that Mars does have life, and ongoing scientific investigations using both spacecraft in orbit and landers on the surface have sought whatever evidence is available. It now appears that conditions were once amenable to life, albeit primitive, with indications that the apparently bone-dry planet was once much wetter and had a thicker atmosphere. That of course is not proof that there was life, just that it was possible.

A few decades back intriguing evidence turned up in an unexpected place, namely on the icecap of Antarctica. It took the form of a meteorite, one of some 7,000 gathered by search parties since the 1970s. Found in December 1984 in the Allen Hills region, it was given the catalogue name ALH 84001. Weighing just less than two kilograms, it looked like a large potato and was partly covered in a black glassy crust, the consequence of being partly melted as it fought its way through the Earth's atmosphere.

Dating using natural radioisotopes and other technologies suggested its life history. Indications were that the rock which formed ALH 84001 had originally hardened from molten lava on some planet or moon about four billion years ago, before much later being blasted into space by the impact of an asteroid. The internal shock damage caused by that immense event can still be seen within the meteorite. Its time in orbit around the Sun before being captured by the Earth could be estimated from the results of collisions with cosmic rays, which suggested about 16 million years of wandering. Its location in Antarctica indicated it arrived about 13,000 years ago.

It is generally believed that the meteorite came from Mars. The strongest evidence for this comes from the traces of gas trapped



It has been suggested that tiny structures on meteorite ALH 84001 are fossilised Martian nanobacteria. NASA/JSC/STANFORD U.

within it. These gases represent a fragment of the atmosphere of the planet from which it had been blasted. The mixture of gases matched the known atmosphere of Mars quite closely and was very different from that of Earth, Venus or any other planet's atmosphere that has so far been analysed.

Another intriguing piece of evidence was the presence within the meteorite of tiny globules of carbonate materials, of a kind most likely to be produced when some sort of liquid, perhaps water, penetrated the rock about 3.6 billion years ago. That also points us towards the Red Planet, since there is growing evidence that water once flowed on Mars either on the surface or underground. The carbonates were precipitated at a temperature of about 18°, which is very much warmer than Mars is now.

But the real excitement came on August 6, 1996, when NASA announced that the meteorite appeared to contain a tiny structure, which some observers quickly described as a fossil, implying some evidence remaining of a primitive life form. The 'fossil' looked like a tiny tube, considerably less than a micron in diameter (and therefore much less than 100th the width of a human hair). It was located within the carbonate globules just mentioned, and therefore gives a possible geological timing

for the existence of a lifeform (if that was indeed its origin).

The immediate response from those sceptical of this suggestion was that the 'fossil' was very much smaller than any known microorganism on Earth, which are a few microns in diameter. But there had been discussion for some years about the possibility of 'nanobes', much smaller than microbes, existing on Earth. Perhaps this was an example. The meteorite contains some organic compounds and some of the structures which could be associated with biological activity.

If the structure within the meteorite was actually a fossil, we would have the first evidence of a life of any kind having existed elsewhere than on Earth. That would indeed be a very exciting find, and at the time it was seen as so significant that the US president made an announcement about it.

Since that time similar structures have turned up in other Martian meteorites, which could be taken to strengthen the case that they really do represent traces of life. But all the supporters of this idea really have to go on at the present time is the shape of the structures, and the doubters think that that is by itself an unreliable guide. Better information would come from analysing the chemical composition of the structures, such as the ratio of carbon isotopes within them, but available techniques are not yet able to deal with structures so tiny.

So on this matter, as on the more general question of life on Mars, we must accept that the jury is still out. But with the pace of exploration of Mars, with new landers and orbiters now arriving every couple of years to carry on the search, it is likely we will have new evidence to go on very soon. ♦

David Ellyard presented SkyWatch on ABC TV in the 1980s. His *StarWatch StarWheel* has sold over 100,000 copies.



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Capturing impressive deep-sky astroimages is easier than ever with Celestron's new Rowe-Ackermann Schmidt Astrograph, the perfect companion to today's top DSLR or astronomical CCD cameras. This fast, wide-field f/2.2 system offers two huge advantages over traditional f/10 astroimaging: better apparent tracking and shorter exposures. That means you'll create better-looking astroimages in a fraction of the time, even without the use of an autoguider.

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Pluto: mission accomplished!

"Home run! New Horizons is returning amazing results already. The data look absolutely gorgeous, and Pluto and Charon are just mind blowing." Alan Stern, principal investigator for New Horizons at the Southwest Research Institute (SwRI) in Colorado, speaking moments after the release of the first close-up images of the surface of Pluto, was understandably elated. As leader of the New Horizons team, he had shepherded the mission from when it was just a concept on paper, through to a flawless fly-by encounter almost nine and a half years after launch.

Around 9:50pm, Australian

Eastern Standard Time, on July 14, New Horizons reached its closest point to Pluto as it zipped past at around 50,000 kilometres per hour. Out of touch with mission control at the time (its design meant it couldn't take images and communicate simultaneously), the dozens of people in mission control at the Johns Hopkins University Applied Physics Laboratory, and millions of people around the world could only watch the countdown clock and keep their fingers crossed that everything was proceeding smoothly.

They needn't have worried. Just hours after that critical point, New Horizons fired off a bunch of signals to Earth to say it was in good shape

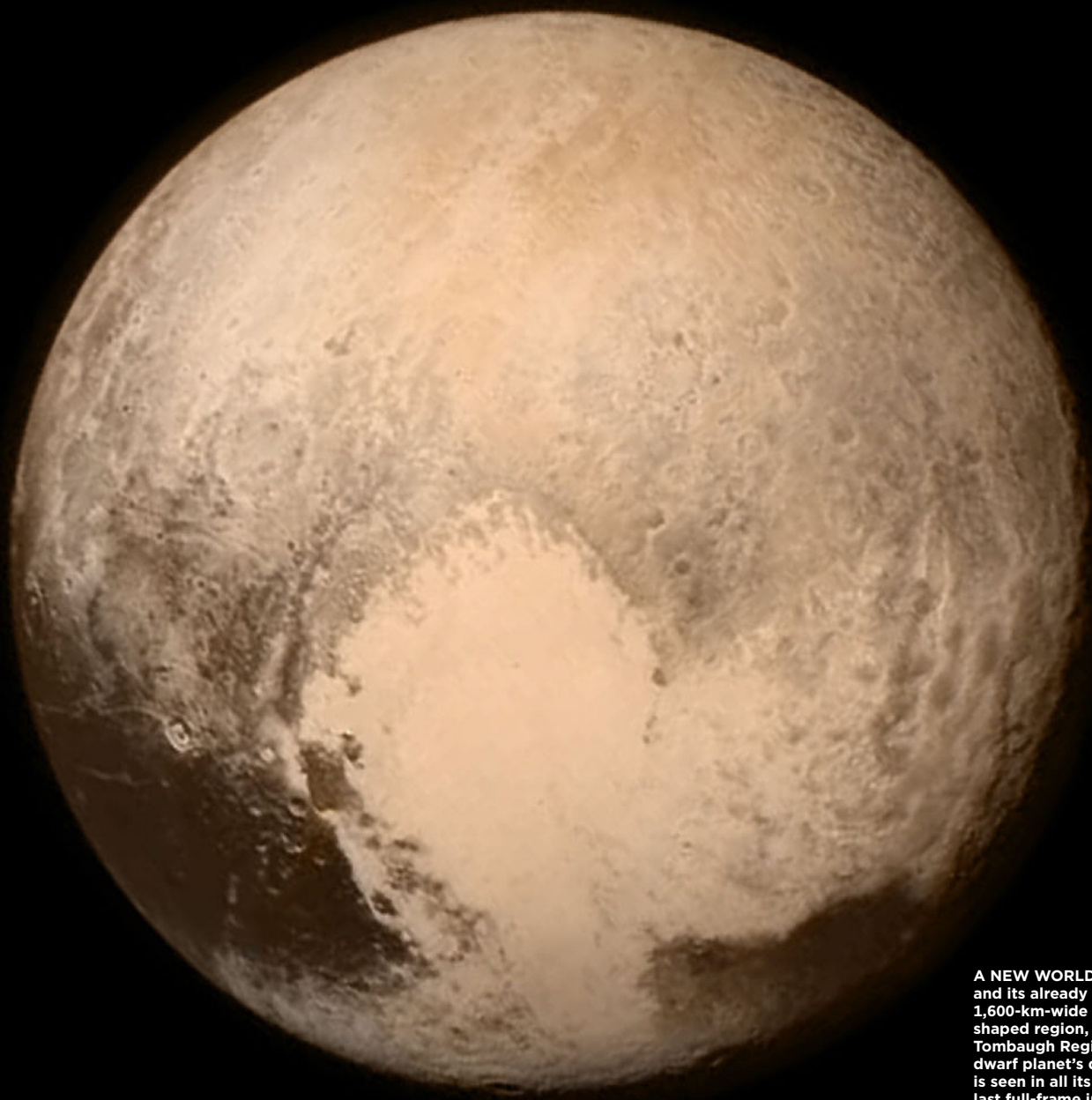
and had successfully completed all of its imagery and data collection tasks. And with that, the final unexplored major Solar System body was a stranger no longer — 50 years to the day since NASA's Mariner 4 had sent back the first close-up images of another planet, Mars.

Now, we'll all have to wait patiently as New Horizons slowly sends back the reams of data and thousands of images it has taken. Due to its huge (and increasing) distance from Earth, and low radio power, the data has to be sent back very slowly. It's going to take about 16 months for it all to be received. It's almost as if the spacecraft will be tantalising us, drip feeding the waiting scientists and the general public with a slow flow of wonders. But given that it has been 85 years since Pluto was discovered, and after a journey of almost a decade, I suppose we can wait a little longer.

The images presented on these pages were taken in the days leading up to and around the encounter, and include the first close-up image of Pluto's surface, released one day after closest approach. We look forward to bringing you more images of this amazing double-planet system in the months ahead.

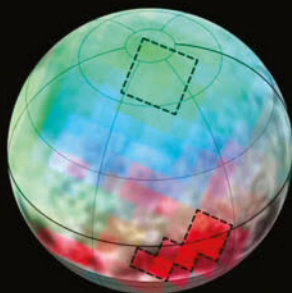
HAPPY FACES The New Horizons mission has involved hundreds of scientists, engineers and technicians during all phases of the project — design, construction, launch, deep space cruise, tracking and communications, the encounter, and now the data analysis to come. After a journey of more than 9 years, it's no wonder there was jubilation at mission control when the moment of closest approach to Pluto arrived. NASA/B.JINGALLS



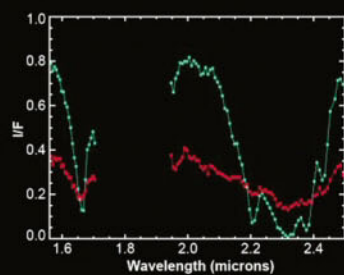


A NEW WORLD Pluto and its already famous 1,600-km-wide heart-shaped region, now named Tombaugh Regio after the dwarf planet's discoverer, is seen in all its glory in the last full-frame image taken before closest approach. The distance from the spacecraft to Pluto was about 768,000 kilometres.
NASA/JHU APL/ SWRI

Methane on Pluto



Infrared Spectral Image



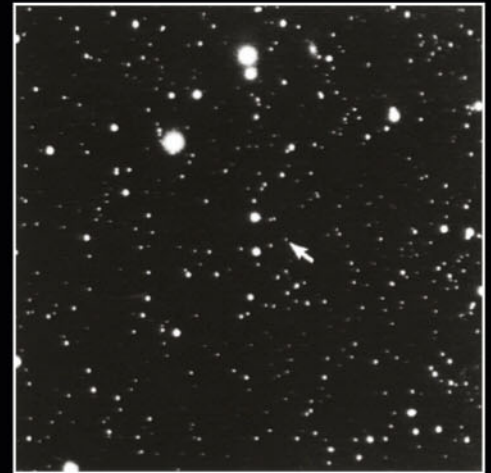
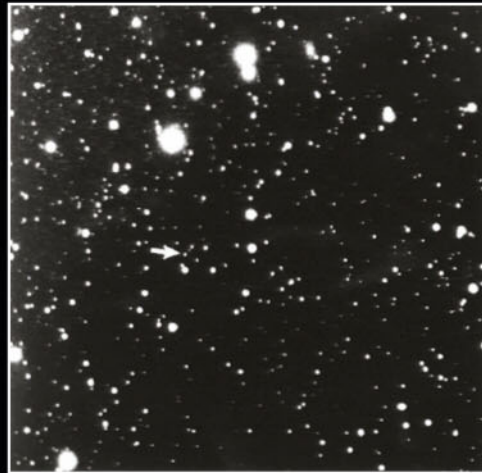
ICY POLE This image from New Horizons' Linear Etalon Imaging Spectral Array shows the coverage of methane ice across the surface of Pluto. Already, scientists can see that there is wide variation from region to region. The spectrum plots come from the two highlighted areas; one from near the north pole (green) and the other from near the equator (red).

NASA/JHU APL/ SWRI

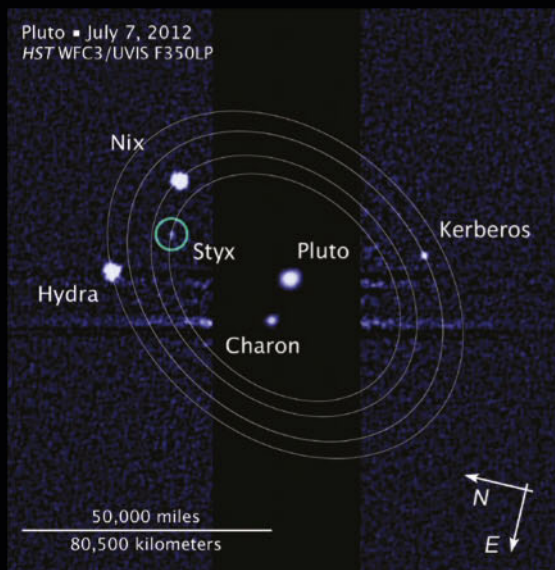
The outer limits

Exploring a double planet

Pluto and Charon are unique in the Solar System, with some scientists considering them to be a double planet. This is because of Charon's large size compared to its 'parent'... unlike most moons, which are tiny compared to their host planets. (To be fair, many of those same scientists consider the Earth and our Moon to be a double planet too, since the Moon is quite large.) The New Horizons mission is giving us our first up-close look at the distant pair. These early images were released in the days leading up to, and the day after, closest approach on July 14. We'll bring you more imagery in future issues.



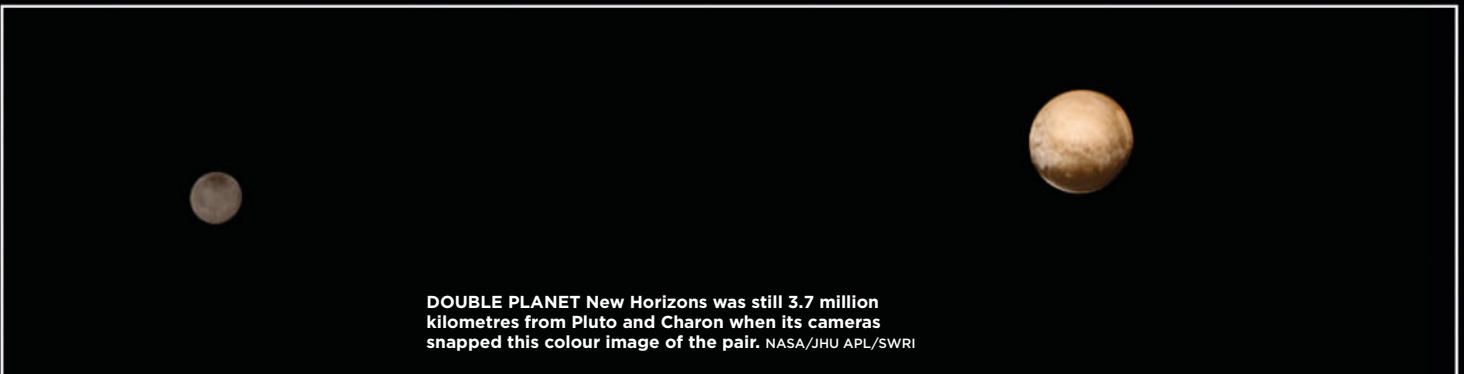
THE NINTH PLANET Pluto was discovered on February 18, 1930, by a young astronomer, Clyde Tombaugh, working at the Lowell Observatory in Arizona. Tombaugh noticed a tiny dot that had moved in the six days between images taken on January 23 (left) and January 29. LOWELL OBSERVATORY



FAMILY PORTRAIT Pluto has five known moons, shown in this Hubble image from 2012. Charon was discovered in 1978, Nix and Hydra in 2005, Kerberos in 2011 and Styx in 2012. In keeping with tradition, all of the names were chosen from mythologies of the underworld. NASA/ESA/L. FRATTARE (STScI)



THE SPOTTY SIDE Because New Horizons zipped past Pluto so quickly, it was able to get close-up images of only one side of the dwarf planet. This image, taken from a distance of 4 million km, shows the other side. Astronomers and geologists are intrigued by the different features in the terrain. NASA/JHU APL/SWRI

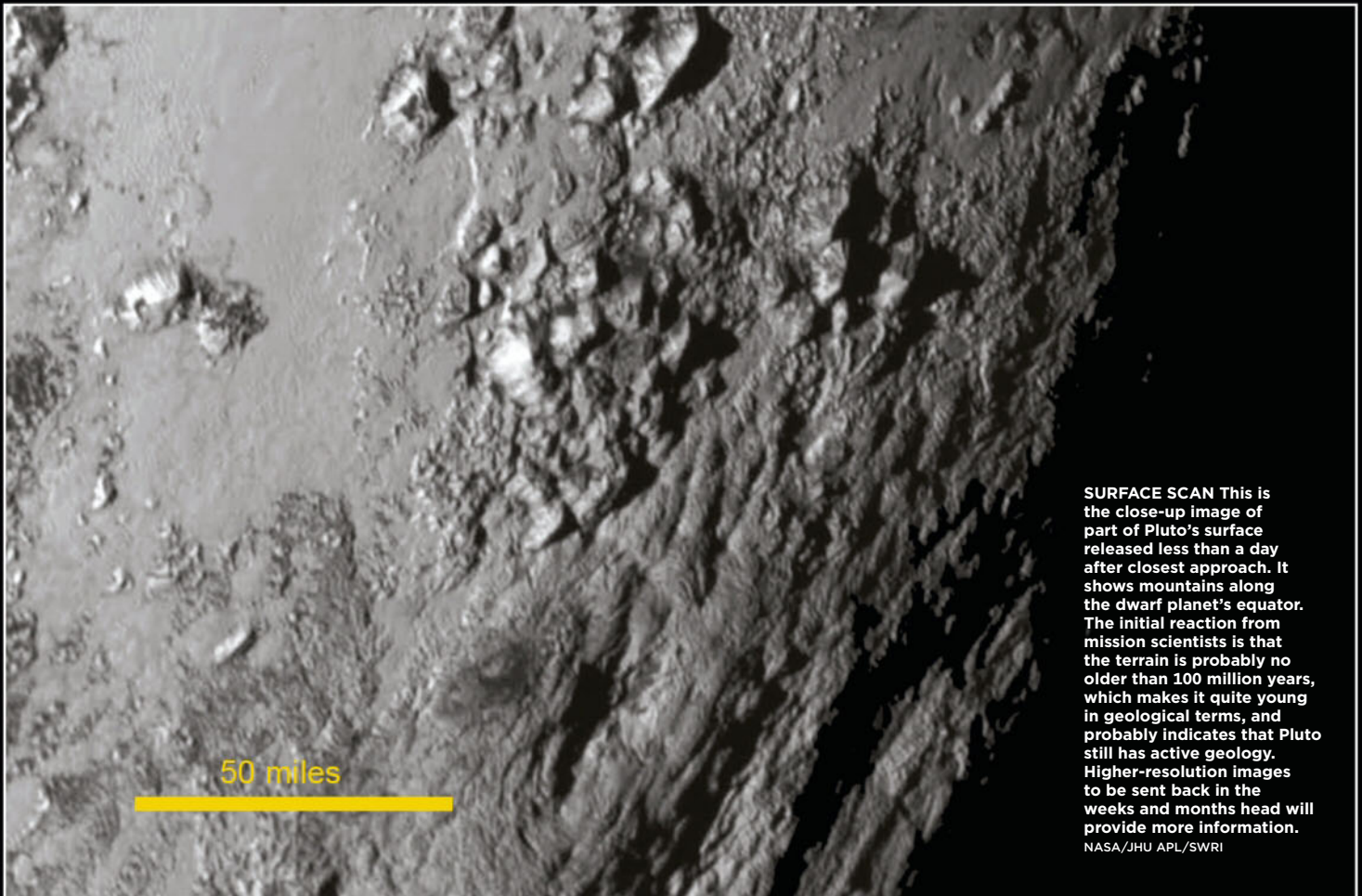


DOUBLE PLANET New Horizons was still 3.7 million kilometres from Pluto and Charon when its cameras snapped this colour image of the pair. NASA/JHU APL/SWRI

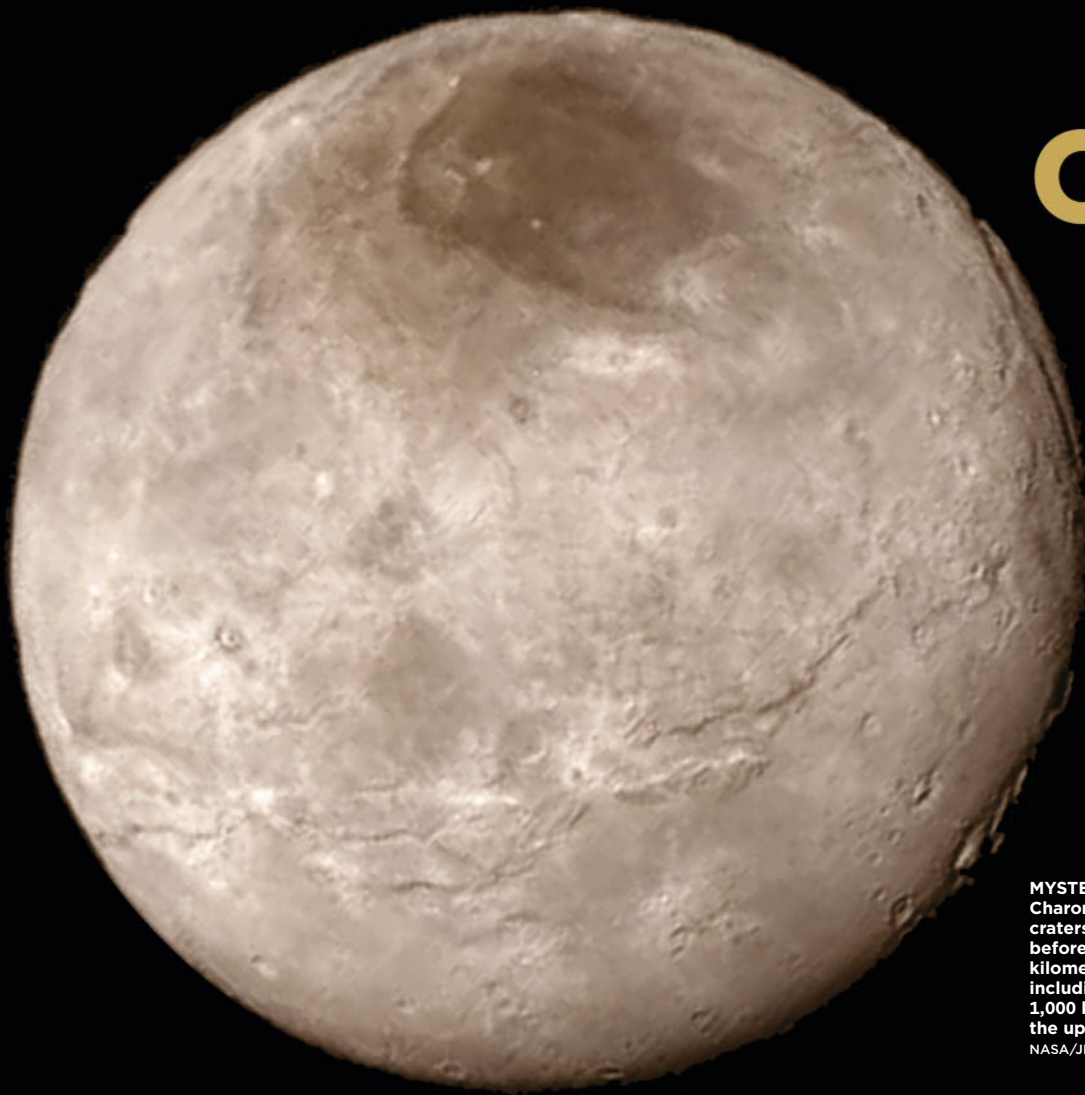
COLOURFUL COMPOSITION These images of Pluto (left) and Charon are presented in false, exaggerated colour to bring out details in the chemical composition of the bodies' surfaces. The distance between the two worlds has been reduced too. Scientists will use images such as these to tease out the chemical make-up and history of the dwarf planet and its largest moon. NASA/JHU APL/SWRI



HELLO HYDRA New Horizons' speed and trajectory meant that it wasn't able to get close-up images of all of the five moons. But a lot can be learned from lower-resolution images. This shot of Hydra gives scientists a better handle on its size, which is approximately 43 x 33 kilometres. NASA/JHU APL/SWRI



SURFACE SCAN This is the close-up image of part of Pluto's surface released less than a day after closest approach. It shows mountains along the dwarf planet's equator. The initial reaction from mission scientists is that the terrain is probably no older than 100 million years, which makes it quite young in geological terms, and probably indicates that Pluto still has active geology. Higher-resolution images to be sent back in the weeks and months ahead will provide more information. NASA/JHU APL/SWRI

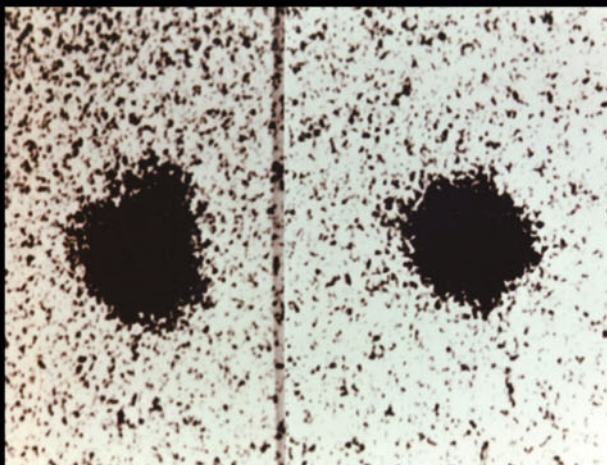


Charon

The largest of Pluto's five moons, Charon, has surprised scientists by revealing a youngish and complex surface, unlike the crater-battered terrain many of them had expected to see. "Originally I thought Charon might be an ancient terrain covered in craters. Many people on the team thought that might have been the case," said Cathy Olkin, a mission scientist from the Southwest Research Institute. "And so Charon just blew our socks off when we had the new image today."

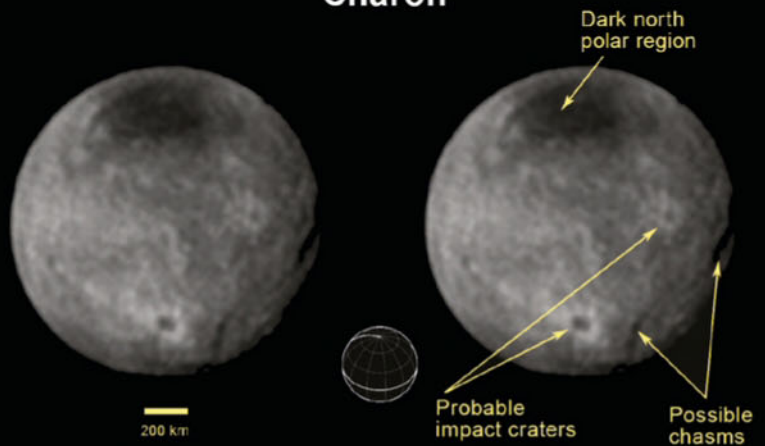
MYSTERY MOON Many scientists were expecting Charon to look a lot like our Moon - plastered with craters. But this New Horizons image, taken the day before closest approach from a distance of 466,000 kilometres, shows a much more interesting terrain, including a network of troughs and cliffs spanning 1,000 km on one side of the globe. The canyon on the upper right edge is about 7 to 9 km deep.

NASA/JHU APL/SwRI



LUCKY DISCOVERY Charon was discovered accidentally in 1978 when astronomer James Christy noticed a fuzzy blob extending from the side of Pluto, in fuzzy images taken with a ground-based telescope. By going back and looking at earlier images, he again saw the blob, and it appeared to be circling Pluto in a little over six days. It could only be a moon. The discovery was officially announced on July 7, 1978, and Christy proposed calling it Charon - the mythological underworld ferryman who punted souls across the river Acheron. The name was formally adopted in February 1985. US NAVAL OBSERVATORY

Charon



CHASMS AND CRATERS Taken three days before closest approach, these images of Charon began to reveal the moon's interesting surface features - including a dark area nicknamed 'Mordor' in the northern polar region. The larger image (top of page) has shown this area to have a diffuse boundary, suggesting it is a thin covering of dark material. NASA/JHU APL/SwRI

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Naming the Craters



The man who put the names on the



Moon

Giambattista Riccioli had a grander plan than meets the eye — and perhaps a secret agenda.

One benefit of binoculars is their big-picture view. Take the Moon. Looking at it with only 8 or 10 power makes you focus on larger issues, such as why did the second-quarter (waxing gibbous) Moon get the oceans with the ominous names? And what's that gulag of ancient Greek astronomers doing, shivering on the shores of the Sea of Cold? Why are the crater names beginning with Al- so concentrated in the south? And why was the great Galileo assigned such an insignificant little out-of-the-way crater that you need 20× to spot it?

The man to ask, the man with the plan, the man who named all the major features on the Moon, was the Italian Jesuit astronomer Giambattista Riccioli (1598–1671).

Riccioli published his landmark Moon map in 1651, just 42 years after Galileo first turned a telescope to the heavens and saw that the Moon was rough and mountainous — and 18 years after the Inquisition sentenced him for advocating the Copernican system of the Earth and planets

revolving around the Sun. Riccioli's map of the Moon was the best one yet. Its detail and accuracy are impressive considering the small, primitive, hard-to-use telescopes of the time.

And all those features on the map needed names.

Look at the Moon's celestial eastern limb and just south of the equator — there Riccioli named a modest crater for himself, giving him the easternmost ringside seat on his handiwork. Next to him is his assistant Francesco Grimaldi, who drew the map. Then comes the Polish astronomer Johannes Hevelius, who had recently published his own Moon map, in 1647, featuring a grab bag of royals, religious figures, scientists and explorers. Finally, on the opposite side sits Langrenus, whose earlier (1645) map had used neutral but head-scratching obscure names from Greek and Latin geographies. Riccioli left him in his own chosen place on the shores of Mare Fecunditatis. There they are, the three pioneers of selenography, except it was pretty much winner-take-all for Riccioli.



ANDREW
LIVINGSTON

What made his names such a success? And why do we use most of them today?

The Moon's eight octants

Riccioli divided the Moon into eight slices like a pizza, drawn on his map and labelled around the edges as seen on the facing page. They start in the celestial northeast with "I Octans"... upper left on the map. An odd place to start? Watch what happens. Working around clockwise in a historical timeline, Riccioli sprinkles the Moon with ancient Greeks, followed by Romans and early Christians, then medieval scholars both Christian and Muslim, to end with a grand finale of his fellow moderns in VIII Octans, the easternmost and last to be well-revealed as the Moon waxes to full.

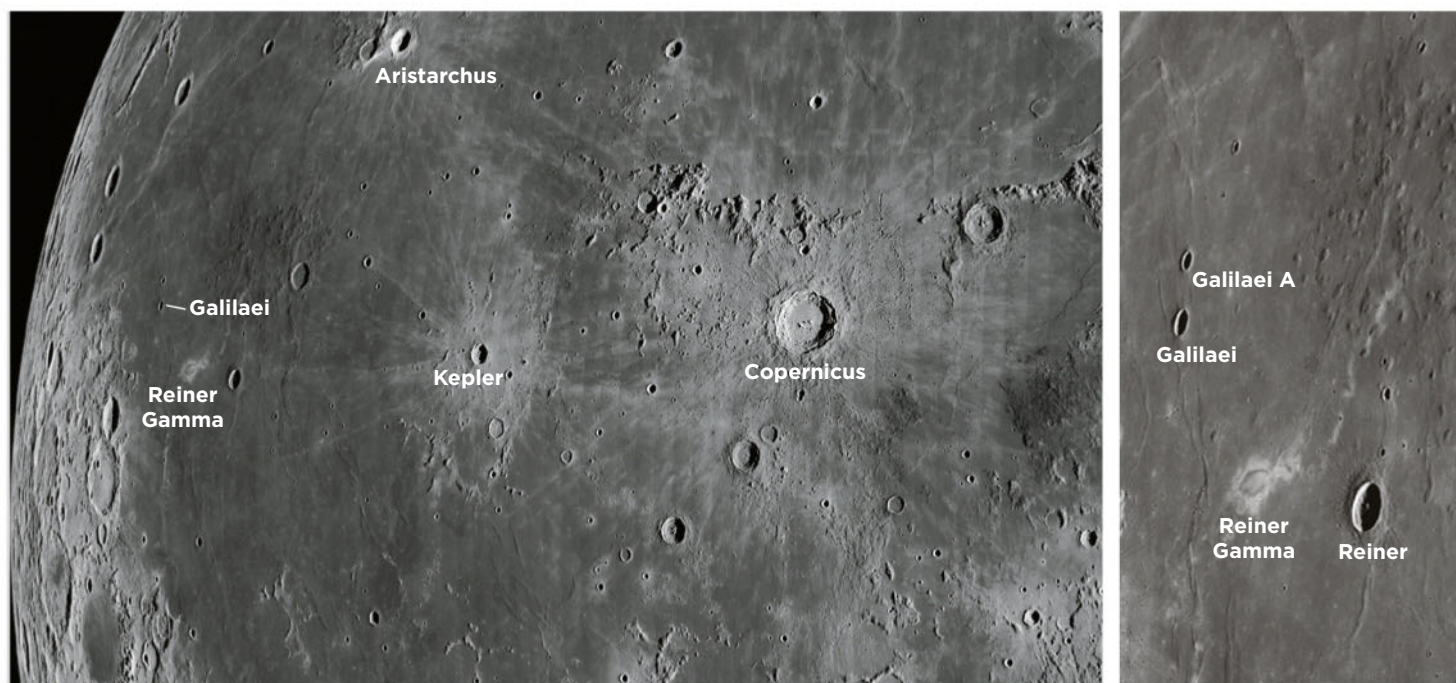
Riccioli didn't always follow this design strictly. Some eras spill out of their octants, and along the southern limb from Langrenus onward are more of Riccioli's contemporaries — new authorities taking their seats opposite the ancients.

Hold the Latin!

Sorry, not an option. In Riccioli's day, scientists not only published in Latin (Galileo was an exception) but were

NAMING OF PARTS Riccioli's Moon map, from his *Almagestum Novum* (1651). The subhead says, "Men neither live on the Moon. Nor do their souls go there." Riccioli's rebuke of those popular fancies is ironic — thanks to him the Moon is full of famous men. And a few women.

ALMAGESTUM NOVUM



THE COPERNICANS Aristarchus, 'the Greek Copernicus,' is placed above Galileo, Kepler and prominent Copernicus himself. **Right:** Riccioli didn't intend Galileo to end up with the tiny crater so named today. He applied the name to what's now called Reiner Gamma: an odd, flat, light marking, part of a streamer with unusual magnetism that may have been left by a comet's ion tail. NASA/LRO (2)

usually known by Latinised names. Which gives the moderns on the Moon a deceptively antique flavour. Regiomontanus in VI Octans, for example, was born Johannes Müller von Königsberg ('Regent's Mount') in 1436. A Johnny-come-lately by lunar standards, he was the assistant of Purbachius, the crater above. After Purbachius' sudden death in 1461, Regiomontanus found himself finishing off his master's update of Ptolemy's *Almagest*. They had been in Italy, invited by the scholar Cardinal Bessarion, who'd gotten his hands on an *Almagest* in the original Greek; you'll find Bessarion north of Kepler (note that Riccioli often used the obsolete long s, which looks almost like an f). Regiomontanus ended up in Nuremberg, a scientific centre where the wealthy Bernhard Walther helped him build the first scientific printing press. Valtherus, now Walter, is positioned just below Regiomontanus as if to support him. Walther's house, later bought by Albrecht Dürer, is a Nuremberg landmark to this day.

A quick tour of the octants

I and II Octans: Ancient Astronomers On Ice. The north polar region glitters with ancient Greeks. Plato, Aristoteles,

Archimedes and Eratosthenes are the leading lights, but who outshines them all? For Riccioli it was evidently Aristarchus of Samos (circa 310–230 BC), Copernicus' predecessor who first proposed a Sun-centred Solar System with the planets in the right order and the stars far away. Riccioli assigned him the brightest marking on the Moon. After he had been ignored in favour of Aristotle and Ptolemy for almost two thousand years, Riccioli's map brings things literally full circle — Aristarchus' neighbours to the south at the end of the timeline are the Copernican astronomers of VIII Octans.

But here Riccioli, a Jesuit priest, was treading on politically risky ground — just 18 years after Galileo had been forced to denounce Copernicanism and was dealt a life sentence of house arrest. Elsewhere, in public, Riccioli was quite the orthodox anti-Copernican, as displayed on his book's frontispiece. But did he harbour secret Copernican sympathies? More on this later.

III Octans, outer: Sunset Myth. Shortly after new Moon, when the crescent hangs in the west after sunset, the legendary Greek strongmen Hercules and Atlas stand boldly on the terminator. Hercules' second-to-

Julius Caesar earns his place here thanks to the Julian calendar, which brought the dates back in line with the seasons for centuries to come.

last labour was to retrieve the Golden Apples of the Sun, apples that gave you immortality. Guarded by a serpent, they grew in the Garden of the Hesperides, the Sunset goddesses, at the western end of the world where Atlas stood holding up the heavens. Since the Hesperides were Atlas' daughters, he agreed to fetch the apples if Hercules relieved him of his burden. Note how Hercules, of mixed birth, gets the smaller crater while Atlas, the 100% god with the full-time job, gets the larger.

III Octans (inner) and IIII: Rome. Julius Caesar earns his place here thanks to the Julian calendar, which brought the dates back in line with the seasons for centuries to come. (When the calendar needed another tune-up by 1582, Pope Gregory turned to

Aloysius Lilius and Christopher Clavius, duly cratered in VI Octans.) Manilius is next door for his epic poem *Astronomica*. Agrippa to his south wasn't the famous martial son-in-law of Augustus, but a later Greco-Roman astronomer about whom we know next to nothing except that Ptolemy mentioned him observing an occultation of the Pleiades in AD 92.

III Octans raises the question: What's a Sea of Crises (Mare Crisium) doing among the serene, tranquil seas of the first quarter? Riccioli followed a separate scheme for naming the maria; they seem to follow contemporary popular ideas about the influence of the Moon's phases on moods and weather. New Moon, for instance, was a time of changes — times of crises. But there may be a Roman connection here too. Perhaps Riccioli was referring to the persecution of the early Christians by ruthless emperors such as Nero, who was quite unimproved by the philosopher Seneca being his tutor. Seneca, held in high regard by the Church, got a crater for his efforts.

Later we move down to Firmicus, astrologer-polemicist to the first Christian emperor, Constantine. The now defunct Terra Mannae, Land of Manna, is populated by early Catholic scholars such as Dionysius Exiguus, the 6th-century monk who devised our AD chronology of years, and

Abbot Alcuin of York, advisor to Charlemagne. Alcuin's gone from modern maps; his dubious astronomical credentials got him swapped out for a more recent Englishman, Sir John Lubbock.

V Octans: Christianity Triumphant. The prominent crater trio Theophilus, Cyrillus and Catharina lived in Alexandria, which got them seaside locations on Mare Nectaris. Fourth-century Alexandria was the New York of its time, and Saint Theophilus was its crusading bishop. His destruction of the famous temple of Serapis symbolised the final triumph of Christianity over paganism. His nephew Saint Cyrillus followed in his footsteps by banishing the Jews.

Hypatia, above them, is the only astronomer here, with a crater nearby for her father, Theon Junior. (His neighbouring senior namesake lived three centuries earlier.) The pagan Hypatia, a remarkable scholar, Neoplatonist philosopher and mathematician, came to a sticky end thanks to Saint Cyrillus. Her gruesome death at the hands of Cyrillus' agents in AD 415 could be said to have marked the end of the classical world.

Saint Catherine's martyrdom parallels Hypatia's; she is said to have been a brilliant Christian philosopher condemned to death by the last pagan emperor, Maxentius, who didn't

appreciate her attempt to convert him. No record of her exists until 500 years later; some historians believe she was invented to be a counter-martyr to Hypatia. Both are among the very few women on the Moon.

And how does astronomy fit into this business? Hardly at all. Saint Catherine was highly venerated in the Middle Ages; let's guess that Riccioli, with an eye to any criticism that might come for including the Copernicans on the other side of the Moon, was banking a few points with the Church.

VI Octans. Arab Astronomy Takes a Bow. European astronomers knew how indebted they were to the Arab world. The highlight of the terminator at half Moon is the grand Ptolemaeus-Albategnius-Alphonsus-Arzachel group, with Hipparchus, the greatest of the ancient observers, presiding. Ptolemaeus (Claudius Ptolemy, an Alexandrian Greek c. AD 90–160) gets the biggest crater. Throughout the Middle Ages his *Almagest* (from al-majisti, 'Great Treatise') was the astronomy textbook. (Thebit, aka Thabit ibn Qurra of Harran and Baghdad, was a notable translator). Ptolemy's heliocentric model of the Solar System, with its awkward circling circles, did a respectable job of predicting the motions of the planets. Albategnius was the 9th-century Syrian al-Battani, whose extremely accurate trigonometry



OPPOSITE MARTYRS The prominent twin craters of the Mare Nectaris region went to the Christians of the Hypatia episode; Hypatia received just a little one. What's interesting is that she's here at all. She and Catharina, two of the Moon's very few women, both died for their beliefs and were placed on opposite sides of Theophilus and Cyrillus. *Right:* Mathematician or witch? Rachel Weisz played Hypatia in the movie *Agora* (2009). Two centuries after Hypatia's death, the Coptic bishop John of Nikiû described her as a pagan 'devoted at all times to magic, astrolabes, and instruments of music, and she beguiled many people through her Satanic wiles.'

Naming the Craters



SHOULDERS OF GIANTS Ptolemy got pride of place with a grand walled plain near the Moon's centre. Below him gather some of his astronomical descendants, the Arabs who laid the foundation for European astronomy.



NAME-DROPPING Riccioli honoured some of his own contemporaries in the final octants of his map, no doubt helping to ensure its acceptance.

tables were used by Copernicus and Tycho. Alphonsus (Alfonso X 'the Wise,' King of Castile, 1221–84) bankrolled the Alfonsine Tables of planetary positions based on the calculations of Arzachel (al-Zarqali, 'the Engraver') in Muslim Spain. Arzachel (1029–87) was a leading astronomer and instrument maker, and perfecter of that medieval multi-tool, the astrolabe.

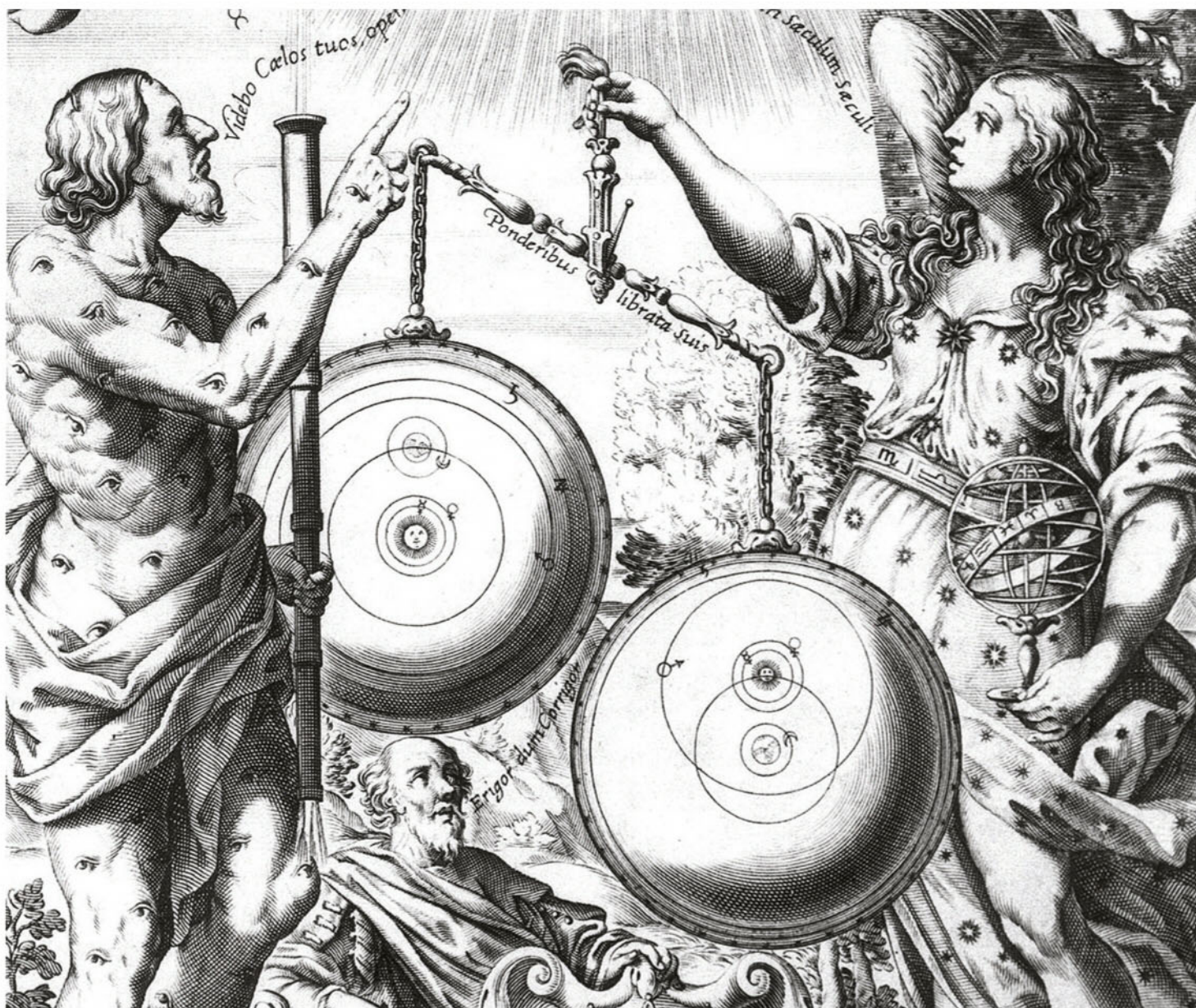
VII Octans. Sunrise on European Science. Philosopher-priest Pierre Gassendi (1592–1655, France) gets the top spot on Mare Humorum, perhaps for being the first to observe a transit of Mercury in 1631, perhaps for trying to reconcile religious belief with a skeptical, scientific outlook, a problem that never goes away. His seaside neighbour Mersenius (Marin Mersenne, 1588–1648, France) was a sort of Jesuit Robert Hooke, who in addition to his own research — he was a forerunner of Cassegrain in reflecting-telescope optics — acted as a clearinghouse for all the latest developments.

Byrgius (Jost Bürgi, 1552–1632) was a super-skillful Swiss instrument maker and unlettered genius who invented logarithms, though by the time Kepler convinced him to publish his work (Bürgi didn't know Latin), he had been scooped by the Scot John Napier.

Viete (François Viète, 1540–1603), lawyer and mathematician, was involved in the reform of the calendar until he had a falling out with Clavius, Pope Gregory's scientific advisor. And finally there's Peter Cruger (1580–1639, Germany and Poland), who published many scientific papers and was Hevelius' teacher, appealing to him from his deathbed to pursue astronomy — which Hevelius did in a big way, using fantastically long-focus telescopes. These were a solution to the severe chromatic aberration of the increasingly large single-element lenses that astronomers had been trying to use. Hevelius' beer brewery, which no doubt financed such projects, went out of business only recently.

VIII Octans. Galileo, what were you thinking?! Galileo Galilei (Italy, 1564–1642) is still a delight to read (try *The Starry Messenger*), and not just for his scorched-earth rebuttals of other scientists, many of whom were unfortunately Jesuits. With *Dialogue Concerning the Two Chief World Systems* he really burned his bridges with the Church. Comparing Copernicus' model of the Solar System with Ptolemy's, he couldn't resist giving the name Simplicio to the hapless defender of the geocentric camp. The name was supposedly 'after Simplicius the Aristotelian' of the 6th century, called by some the last great philosopher of pagan antiquity and perhaps a suitable representative for Aristotelianism. But was anybody fooled? The word can also mean 'dunce.' Into Simplicio's mouth Galileo put the arguments of his old friend Cardinal Barberini, now the Pope! The trial of 1633 followed shortly.

This made things awkward for Riccioli when it came to putting Galileo on the Moon. The Church



ANTI-COPERNICUS On the frontispiece of his great *Almagestum Novum*, Riccioli displays the Muse of Astronomy judging Copernicus's Sun-centred Solar System against Tycho's Earth-centred version. The balance beam says, 'Their weights assessed.' Tycho wins and Copernicus loses, the only safe way Riccioli could rule on the question nine years after the passing of Galileo. At the bottom, old Ptolemy says 'I stand corrected.' ALMAGESTUM NOVUM

was not in a forgiving mood; the ban on Galileo's books wouldn't be lifted until the next century. So what was Riccioli to do?

He had already assigned Copernicus, Tycho and Kepler to the splashiest craters, which luckily were all on the waxing-gibbous quarter, the side popularly associated with storms, damp and misery. Tycho on the Southern Highlands was happily high and dry — his geo-heliocentric model, with the Sun and Moon orbiting the Earth while the other planets orbited the Sun, did not contradict the Bible.

But Copernicus and Kepler? They

were tossed on the Sea of Storms (Oceanus Procellarum), with marshes of fogs and putrefaction to the north (Palus Nebularum and Palus Putredinis), twin threats of disease and insanity to the south (Palus Epidemiarum and Peninsula Deliriorum), and a thunder-and-lightning battering from peninsulas Fulminum and Fulgurum to top things off.

Gothic excess? Not for an audience with fresh memories of the Thirty Years' War. A religious war turned political, it had drawn in mercenary armies from across Europe and killed

a quarter to a third of the population of the German states. The German Kepler had danced around disaster while he lived; not so his grave, destroyed by the Swedes in the sack of Regensburg. If Riccioli was using hellish surroundings to launder the Copernicans, perhaps he'd be less likely to get called out for memorialising them so prominently.

Riccioli a closet Copernican?

Next up in the Tycho-Copernicus-Kepler progression was Galileo. But try to spot Galileo's pinprick of a crater! It's invisible through most



'THE MONSTROUS BEAST OF WAR,' detail from a typical flysheet of the time, shows the Thirty Years' War laying waste to the land, pillaging churches and towns, and slaughtering their inhabitants. Were Riccioli's grim waxing-gibbous names a reflection?

binoculars unless you catch it, and its later-named satellite Galilaei A, as twin sparks of light on the terminator.

So what happened? Don't blame Riccioli; only later was Galileo relocated to the insignificant crater that bears the name today. (Beer and Mädler's 1836 map seems to be the culprit.) Riccioli gave Galileo's name to the last bright splash left in VIII Octans: the flat albedo feature Reiner Gamma, which Grimaldi had mistakenly drawn as a largish crater.

Riccioli published his Moon map in his great encyclopedic work the *Almagestum Novum*, a book "no serious seventeenth century astronomer could do without," as John Flamsteed, England's first Astronomer Royal, put it around the 17th century's end. As its frontispiece illustrates dramatically (see previous page), Riccioli held in public that the Copernicans got it wrong. He discusses 77 objections to a moving Earth. Most were variations on 'where's the big wind?', but a couple he thought were legitimate. Where were the Coriolis effects if Earth was spinning? Falling objects and flying cannonballs didn't seem to be deflected. And if the Earth circled the Sun without the stars showing parallax motion, the stars would have to be extremely far away. But the small

telescopes of his day showed them as little disks (now known to be illusory diffraction disks), which at such a distance would make the stars huge beyond belief.

As for the first objection, and as the Jesuit in Riccioli might have suspected, absence of evidence was not evidence of absence. Coriolis effects are significant only on large scales, because Earth is large; they would be demonstrated in the 19th century. So would the stars' parallaxes. Against these objections was the Copernican system's seductive simplicity.

So did Riccioli have his doubts? We'll never know, but it's telling that he gave Aristarchus, the Greek Copernicus, such a blazing beacon unifying the ancient and modern octants, and Copernicus himself a crater second only to Tycho.

The practical purpose for mapping the Moon — so that terminator timings could be used to determine longitude on ocean voyages — turned out to be impractical. But that didn't stop Riccioli's map from becoming a hit with astronomers from Rome to Greenwich. Who could argue with a Hall of Fame, especially if it included them? And hats off to the way Riccioli handled the Copernicans. But the map's enduring appeal was poetic. The

So what happened? Don't blame Riccioli; only later was Galileo relocated to the insignificant crater that bears the name today.

Moon, its gaze fixed upon Earth, had seen a lot of history. Riccioli made it bear witness to all those centuries of observation, speculation and calculation.

As for Galileo getting short-changed, there's a postscript. In the far-off future, a spacecraft orbiting the Moon would discover something unusual — that the Reiner Gamma marking is a magnetic anomaly whose mini-magnetosphere may be shielding it from the darkening effect of the solar wind. Left where Riccioli put him, Galileo would have kept his name in lights, and in binoculars, for millennia to come. ♦

In all his years in advertising, *Andrew Livingston* has never seen such an action-packed layout as Riccioli's map of the Moon. As for Galileo, when binoculars show the Sun rising on his crater, he gets an honorary visit courtesy of a 33-cm Dobsonian.

FURTHER READING

- Antonín Růkl's indispensable *Lunar Atlas* is a labour of love deserving a crater of its own. It includes a wealth of lunar information as well as a who's who on our side of the Moon.
- Ewan Whitaker, *Mapping and Naming the Moon*. This is the 'Almagest' on the topic, by someone who had a hand in directing the International Astronomical Union's lunar nomenclature and in preparing the map used by the Apollo missions.
- C. M. Graney, *Teaching Galileo? Get To Know Riccioli!*, available at arxiv.org/abs/1107.3483.
- Also by Graney: *Giovanni Battista Riccioli's Seventy-Seven Arguments Against the Motion of the Earth*, arxiv.org/abs/1011.3778.

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Planck Upholds Standard Cosmology

The latest analysis of the universe's oldest light provides an exquisite look at the cosmos.

I spent the end of 2014 squirming. For months I'd been waiting for the release of the full-mission data from the European Space Agency's Planck spacecraft. Planck launched in 2009 to study the cosmic microwave background (CMB), the relict radiation from the universe's birth. It's the latest advance in a field fairly young by astronomical standards: 50 years ago this month, Bell Labs' Arno Penzias and Robert Wilson published their landmark detection of the CMB.

The 1965 paper, "A Measurement of Excess Antenna Temperature at 4080 Mc/s" in the *Astrophysical Journal*, is



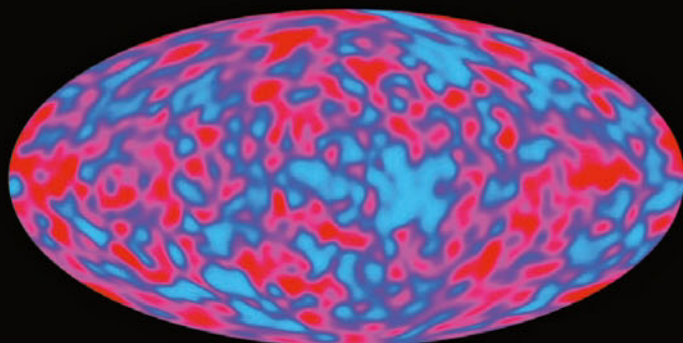
CAMILLE
M. CARLISLE

less than two pages long. Only two paragraphs talk about the "unaccounted-for antenna temperature" Penzias and Wilson had stumbled upon, and the authors politely leave suggestions for its origin to a companion article by Robert Dicke and others at Princeton. (The Princeton folks, who had been hunting for the CMB, had the good grace to accept they'd been scooped.)

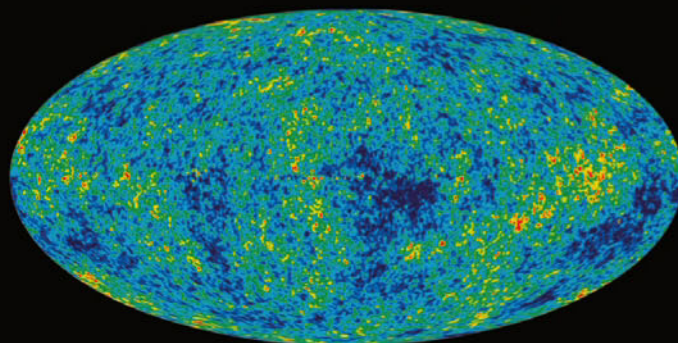
Since then, CMB studies have revolutionised our understanding of the cosmos, giving birth to an era of precision cosmology. Many of us today recognise the splotchy maps,

the pattern they record spawned by density fluctuations in the universe's earliest moment. The CMB might seem esoteric, but it has big implications: the density fluctuations also served as seeds for the growth of cosmic structure, the sprawling web of galaxy clusters in which nearly all matter resides. From dark matter and cosmic expansion to when galaxies first set the universe alight, the remnant radiation touches a boggling number of areas in astronomy. Understanding why the CMB looks the way it does thus helps us understand the entire universe.

COBE



WMAP



Hence my squirming.

Planck observed in nine frequencies spanning 30 to 857 GHz, mapping the CMB's temperature in all nine frequencies and its polarisation in seven, before shutting down on schedule in 2013. The team released the temperature observations from the mission's first 15 months that same year. These data were mostly in beautiful agreement with the standard picture of cosmology astronomers have developed.

Since then, the team has been working feverishly to analyse the full, four-year data set. This past December, members presented those data at a conference in Ferrara, Italy, and the team released most of the 28 official analysis papers in February. (A few stragglers were still in the wings in March.) The results provide a wow-worthy view of the universe and of how precision cosmology works, although if you're like me, you'll need some help to see how this psychedelic picture comes together — and maybe some ibuprofen when we're done.

How astronomers find the universe in the CMB

At first glance, CMB maps look like toddler finger-paintings — colourful, but enigmatic. It's not obvious how cosmologists derive things such as the universe's age from them.

Yet they do. They start with the splotchy CMB pattern. Then they make some assumptions about what kind of universe they're dealing with. In astrospeak, they assume *the standard lambda-CDM model*, the cosmological framework astronomers

currently use. This framework includes:

1. a particular solution to the general relativistic equations of gravity, including an anti-gravity force called the cosmological constant, or lambda (what's now called dark energy);
2. an expanding universe that looks basically the same on large scales;
3. an early period of stupendous expansion called inflation;
4. quantum fluctuations that seeded today's large-scale matter distribution (those density fluctuations I mentioned earlier); and
5. the existence of a type of matter that responds to gravity but not to electrical or magnetic forces (generally called dark matter).

From there, they start tweaking the specific values of different parameters, like a dressmaker tucking and letting out a dress pattern until it fits. They could even chuck any assumption that proves to be wrong. Eventually, they find the pattern that most successfully fits the CMB.

The amazing thing is, this method works. It works *really well*. That's because back when the universe's contents cooled down enough to stop being plasma and release the CMB's photons (about 370,000 years after the Big Bang), the universe was simple, says team member Charles Lawrence (JPL) — basically a hot, bland soup of particles and dark matter, with no chemical reactions going on. So scientists can actually figure out the exact physical setup that would create the CMB we observe.

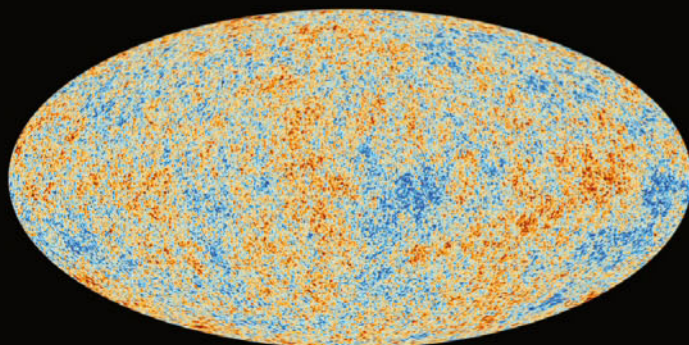
Six numbers tell all

Planck's 2015 release upholds that of 2013, with only slight changes. The results still overwhelmingly favour an early universe defined by only six parameters:

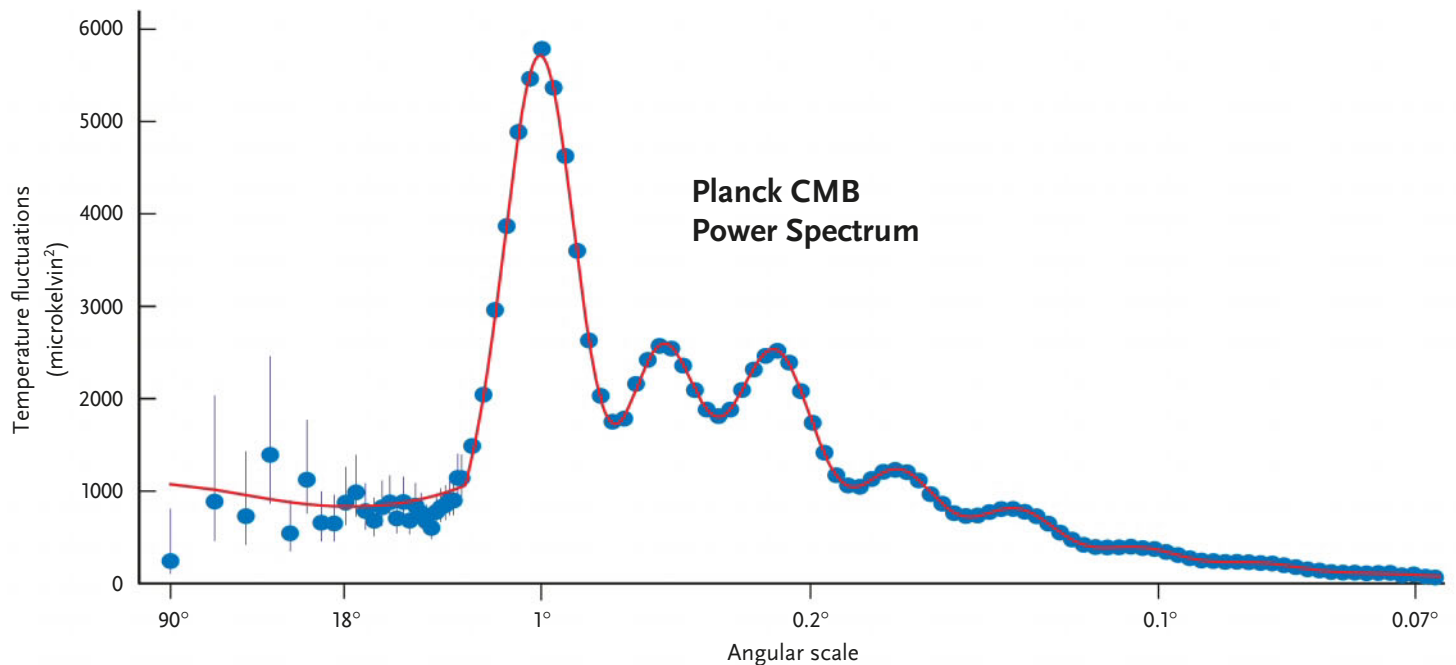
1. The density of baryonic matter (a.k.a. normal matter, like you and me) in the universe's first few minutes;
2. The density of cold dark matter at that same time;
3. How far sound waves travelled from the end of inflation to when the CMB photons were released;
4. The fraction of CMB photons that have scattered off 'free-floating' electrons and protons over the universe's history. These particles were set free by radiation from stars and quasars ionising the neutral hydrogen filling the cosmos. This number is directly related to when the first galaxies had pumped out enough stars to set the universe aglow;
5. The strength of the initial density fluctuations on a scale of about 65 million light-years at the end of inflation. Fun fact: Planck's value of parameter #5 says that, after inflation, the density of matter varied only 0.000000002 across 65 million light-years; and
6. How the strength of the density fluctuations at the end of inflation changes depending on how big a patch of sky you look at.

From these parameters, the team can calculate just about anything you please, such as the universe's age. The exact values depend on which data subsets scientists include in the

PLANCK



our view of the cmb One of our first detailed views of the CMB's temperature spots came from the Cosmic Background Explorer (COBE), launched in 1989. The Wilkinson Microwave Anisotropy Probe (WMAP) followed in 2001 and Planck in 2009. The COBE map here has an angular resolution of 10 degrees, WMAP's is about 15 arc minutes, and Planck's is 5 arc minutes. COBE: NASA; WMAP: NASA/WMAP SCIENCE TEAM; PLANCK: ESA/PLANCK COLLABORATION



MORE THAN JUST WIGGLES This graph is the cosmic microwave background's (CMB's) 'power spectrum'. It plots the magnitude of temperature variations (vertical) at different angular scales (horizontal, approximate). The red line is the standard cosmological model, the blue dots are Planck data. Once cosmologists confirm that the standard model is a good match to the real universe, they can use the power spectrum to determine cosmological parameters — an easier task than fitting directly to the map. The spectrum reveals that temperature variations are strongest on a scale of about 1°. Although there's a tiny dip around 10°, at the moment there's no strong evidence that it requires a physical explanation. S&T: GREGG DINDERMAN, SOURCE: PLANCK COLLABORATION

calculations — and there are reasons for not always using the kitchen sink. In this article, I've chosen to use the version highlighted in the team's overview paper, which includes information from all the temperature and some low-frequency polarisation measurements. It also accounts for the slight blurring in the splotchy pattern created when CMB photons pass massive cosmic structures and are bent slightly from their straight-shot paths by gravity.

Of all the numbers that come out of the results, here are three worth remembering:

- Age of universe: 13.799 $\pm$ 0.038 billion years (note: that means we know the age of the universe to within 38 million years)
- Fraction of universe's content that is dark energy: 69.2 $\pm$ 1.2%
- Universe's expansion rate: 67.8 $\pm$ 0.9 km/s/mega-parsec (a parsec is 3.26 light-years)

The universe's expansion rate, called the Hubble parameter or Hubble constant, not only sets the time scale for cosmic expansion but also the scale for the universe's size and age. When Planck's 2013 results came out, the fact that the team derived a rate

// If astronomers can measure an expansion rate for today's universe that's clearly higher than Planck's value... it would be evidence that something is missing from our cosmology. //

below 70 km/s/Mpc caught attention.

Its predecessor, NASA's Wilkinson Microwave Anisotropy Probe (WMAP), had also found a lower value, in conflict with the 73-and-change value calculated using supernovae. The Planck value is a forward-looking extrapolation, a prediction of how fast the universe 'should be' expanding today, given what we see in the early universe, explains Planck team member Martin White (University of California, Berkeley). So if it's different from what we actually see, that's "a sharp test of our understanding and could potentially indicate new physics, new constituents of the universe, or show we don't understand as much as we think we do," he says.

But several other measurements have now also pushed the Hubble parameter down, so a lower expansion rate might be here to stay. On the other hand, not all measurements have. If astronomers can directly measure a precise expansion rate for today's universe that's clearly higher than Planck's value, then it would be strong evidence that there's something missing from our cosmology.

Of stars and galaxies

The latest Planck data say some interesting things about the universe. One neat result is that the era of reionisation — basically, when the universe's galaxies really started lighting up with stars — is later than estimated using data from WMAP. WMAP had favoured reionisation at a redshift of 10.6 (440 million years after the Big Bang), but Planck pegs it at 8.8 (560 million years after the Big Bang).

"For many cosmologists, I would say that it is a relief," says David Spergel (Princeton), who worked on the WMAP team.

The problem was that astronomers studying early star formation had a hard time explaining the earlier start time from WMAP. Astronomers think



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the universe's first stars formed about 100 million years after the Big Bang; the first black holes came soon after. When stars and black holes madly gobble down gas, they emit light. But the era of reionisation happened when there were so many photons flying around that much of the plain old hydrogen atoms filling the universe lost their electrons and got ionised. (Because everything started out ionised at the universe's birth — no atoms formed until things cooled down 370,000 years in — this is the second time things are ionised, hence 'reionisation'.) And with the earlier WMAP date, there just shouldn't have been enough photons around to break up the hydrogen.

Planck's result makes things better, although not perfect. "We're still kind of short of photons," says Marta Volonteri (Institut d'Astrophysique de Paris), "but with some extrapolations and optimistic assumptions, it seems that galaxies may provide enough photons."

There also remains the strange problem of the missing galaxy clusters. The Planck team finds a certain lumpiness in the CMB, which should match up with the lumps in the distribution of matter in the universe. This distribution manifests as cosmic structure, which is made up of galaxy clusters. But Planck predicts about 2.5 times more clusters than are actually observed. This could be due to error in the estimates from either side, or due to new physics.

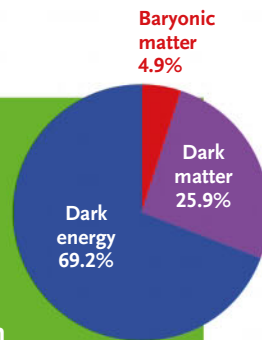
Cosmic inflation and whatnot

Then there are the implications for inflation. No. 6 in the list of parameters (how the strength of the density fluctuations changes with angular scale on the sky) is called n_s , or the *scalar spectral index*. It's important because it describes the state of affairs at the end of inflation, and the fluctuations it measures are the ones that started sound waves sloshing in the universe's primordial plasma, ultimately leading to the CMB we see. Planck finds a value of 0.968, which means that the strength of the fluctuations is slightly larger on larger scales — a tilt predicted by most inflation models. This offset has a slight effect on galaxies' formation rate over time, Spergel says.

For polarisation, there's still no sign

The cosmic pie

The latest Planck results suggest the universe breaks down to 69.2% dark energy, 25.9% dark matter and 4.9% baryonic (or 'normal') matter. But the exact values of these fractions can change by several tenths of a percentage point, depending on the data subsets used and assumptions made — for example, the six different combinations the Planck team lists in its cosmological parameters analysis give a range for dark energy from 68.4% to 69.4%.



COSMIC EXPANSION

The units for the universe's expansion rate, kilometres per second per megaparsec (km/s/Mpc) can be confusing. They mean that, the more distant the galaxy, the faster it's receding from us. Think of the universe like a loaf of raisin bread baking in the oven. If a 'unit' of dough always doubles in size in 10 minutes, then in 10 minutes, two raisins that began 2 units apart will be 4 units apart, but two raisins that were 4 units apart will now be 8 units apart. In other words, because the expansion rate of the dough is the same throughout the loaf, raisins move apart from one another at a speed that's proportional to the distance between them. That's what the units of the Hubble constant (km/s/Mpc) mean: a galaxy is moving away from us at a speed that's proportional to its distance.

of primordial B-modes, the swirly polarisation patterns that would be the signal from spacetime ripples triggered by cosmic inflation. These *gravitational waves* would have various wavelengths, and some waves would be stronger than others, meaning that, like with the CMB's fluctuations, their strength changes depending on how big a patch of sky you look at. Focusing on a scale of 65 million light-years (for convention's sake), the Planck team calculated an upper limit for the ratio of the gravitational waves' strength to the strength of the run-of-the-mill density fluctuations of 0.11. Combining that with the joint analysis done with the BICEP2/Keck Array team gives 0.09. In other words, the gravitational waves' strength must be less than 9%

that of the regular fluctuations.

On their own, these numbers sound like jargon. What matters is that they home in on some of the simpler types of inflation. (By one count, there are four dozen inflation models out there.) These simpler types involve an inflation generated by the decay of a single energy field, a field that decreased slowly compared to the universe's expansion rate — although, given that the observable universe expanded at least 5 billion trillion times in 10 nano-nano-nano-nanoseconds, that's not that slow. The energy scale implied for inflation is less than 2×10^{16} gigaelectron volts, on par with the level expected for the merger of the strong, weak, and electromagnetic forces into one, called the Grand Unified Theory. Physicists



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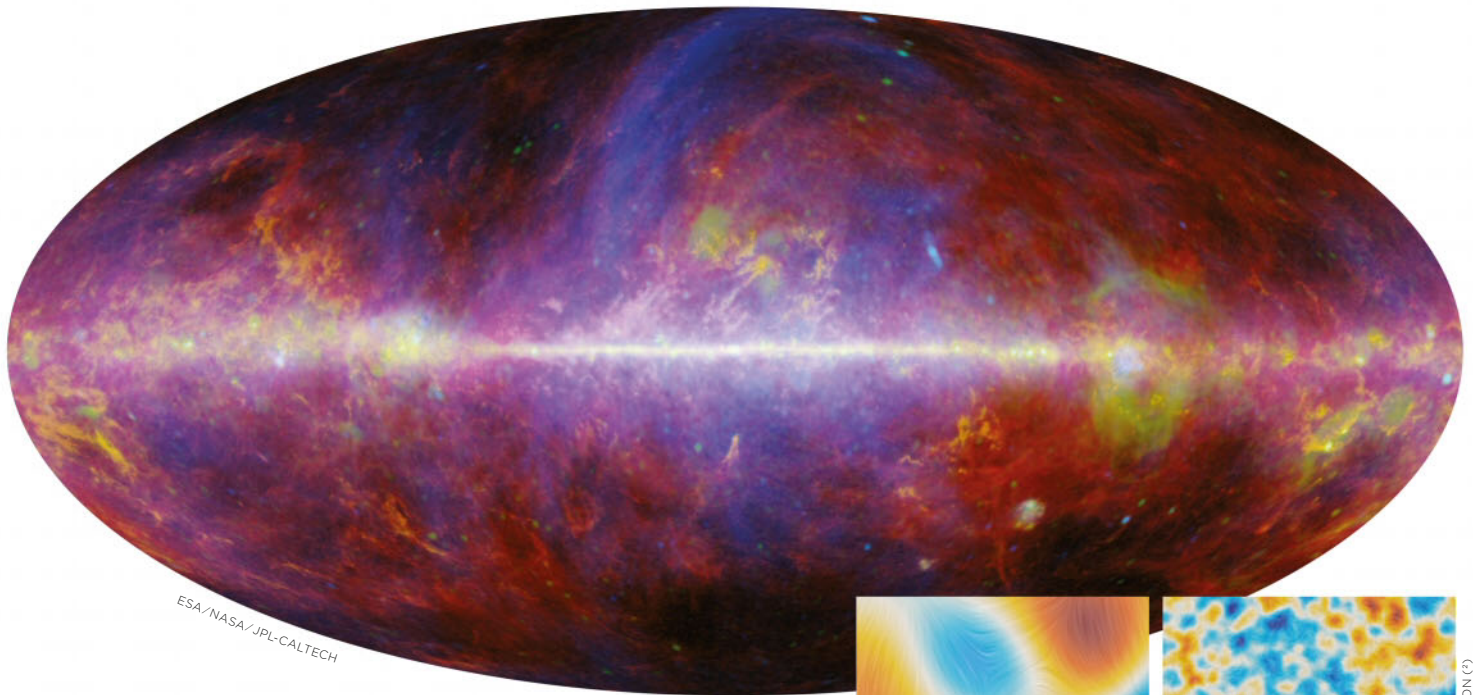
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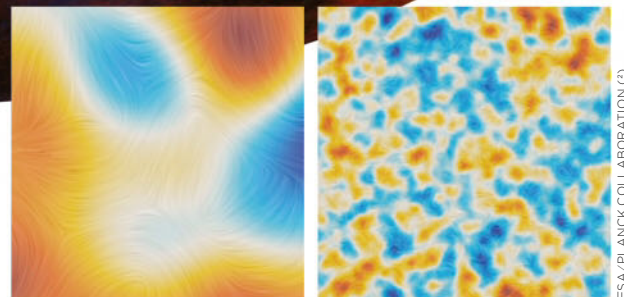


DUSTY VIEW To study the CMB, cosmologists must first peel away all the 'foreground' emission from the Milky Way — a herculean task, as apparent from this false-colour composite. The most widespread feature is dust's thermal glow (red). Also shown are radiation from high-energy electrons corkscrewing through the galaxy's magnetic field (blue); carbon monoxide gas (orange), a tracer for the molecular hydrogen from which new stars form; and emission from hot, ionised gas near massive stars (green). As expected, the last two are concentrated in the galaxy's disk, where star formation is ongoing.

think these forces were united in the first mini-moment of the universe, then broke apart. Their breakup might somehow be connected to inflation.

These are only selections from the cosmology results. Planck also amassed tonnes of information on 'foreground' stuff, such as the dusty Milky Way within which our Solar System twirls, but the team is focusing on the core cosmological science and leaving much of the astrophysics to others. Astronomers have already been playing with Planck's data, and there will be a focus meeting at the International Astronomical Union conference in August devoted to exploring uses for the mission's results. The team will release a final data set in a year, with improved calibration and other fine-tuning. Then they will essentially step aside and leave the riches for the world's astronomers to explore ♦

Every time she writes about cosmology, Science Editor *Camille M. Carlisle* feels like she's knocking her head against a wall, hoping the debris will lodge in her brain.



POLARISATION OF THE CMB A small fraction of the CMB is polarised, meaning the light vibrates in a preferred direction. The photons became polarised in their final encounter with electrons in the primordial plasma soup, before the universe cooled enough for radiation to travel freely. Thus, the CMB's polarisation contains information about the distribution of matter in the early universe, and its pattern follows that of the tiny fluctuations observed in the CMB's temperature. In these maps, colours represent temperature differences, while texture indicates the direction of the polarised light. The all-sky map at the top of p. 26 is filtered to mostly show the signal detected on a scale of 5° (as is the left patch above) on the sky, but Planck detected fluctuations on smaller angular scales as well (right, same patch at $20'$).

Other notable results

In the discussion of what dark matter is, one idea is that it is its own antiparticle; thus, if two dark particles collide, they'll go *poof*. Planck scientists don't need dark matter annihilation to make sense of the CMB, although interpreting what that means for dark matter depends on the properties we assume dark matter has.

A delightful consequence of having to clean Planck's data of other stuff in the universe is all the insight gained about that intervening stuff. As CMB photons pass through cosmic structure, the matter acts as a gravitational lens, bending the photons' path. The resulting zigzag paths slightly blur the CMB's pattern. Because Planck's observations are so precise, the team had to take this gravitational blurring into account. As a result, they created a detailed map of all the matter the photons passed from 370,000 years after the Big Bang until now.



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The Science of Jules Verne's Fiction



DEAN REGAS

Nineteenth-century science and technology shaped two classic tales of imaginary spaceflight.

Under a Floridian sky, three astronauts boarded their metallic spacecraft. As throngs of well-wishers nervously looked on, at the awaited moment the crew blasted up, up into the warm, clear air — soaring toward the Moon. Flying where no human had gone before, they approached the cratered lunar surface, orbited around the silvery orb and beheld the farside of the our natural satellite.

Then the spacecraft returned to Earth and plunged into the Pacific Ocean, where an American naval vessel gathered the intrepid astronauts and carried them safely back to the United States to be welcomed as national heroes.

This is the true story of the Apollo 8 mission, during which three American astronauts circumnavigated the Moon in December 1968. It also happens to be the plot of Jules Verne's 1865 science-fiction classic, *From the Earth to the Moon*, and his 1870 sequel, *Around the Moon*. There are a number of amazing coincidences between the fantasy journey and the real-life mission undertaken a century later.

Verne's research on the latest astronomical discoveries, along with his familiarity with cutting-edge technology, allowed him to construct a realistic journey complete with comedy, drama and education. Like Verne himself, the novels' adventurers were scientifically minded; they hypothesised, explained and debated maths, science, engineering and astronomy throughout their journey. Today, 150 years later, Verne's science-fiction stories provide an illuminating window into 19th-century scientific knowledge.

The year is 1865, and Verne introduces the Gun Club, a fictional organisation in Baltimore. The club's members (who possess, according to one account, "not quite one arm between four persons and exactly two legs between six") are artillery specialists who lament the end of the Civil War. So they must grudgingly turn their efforts to peaceful endeavours. President Impey Barbicane envisions a new course for the club and his country. "It is reserved for the practical genius of Americans to establish a communication with the sidereal

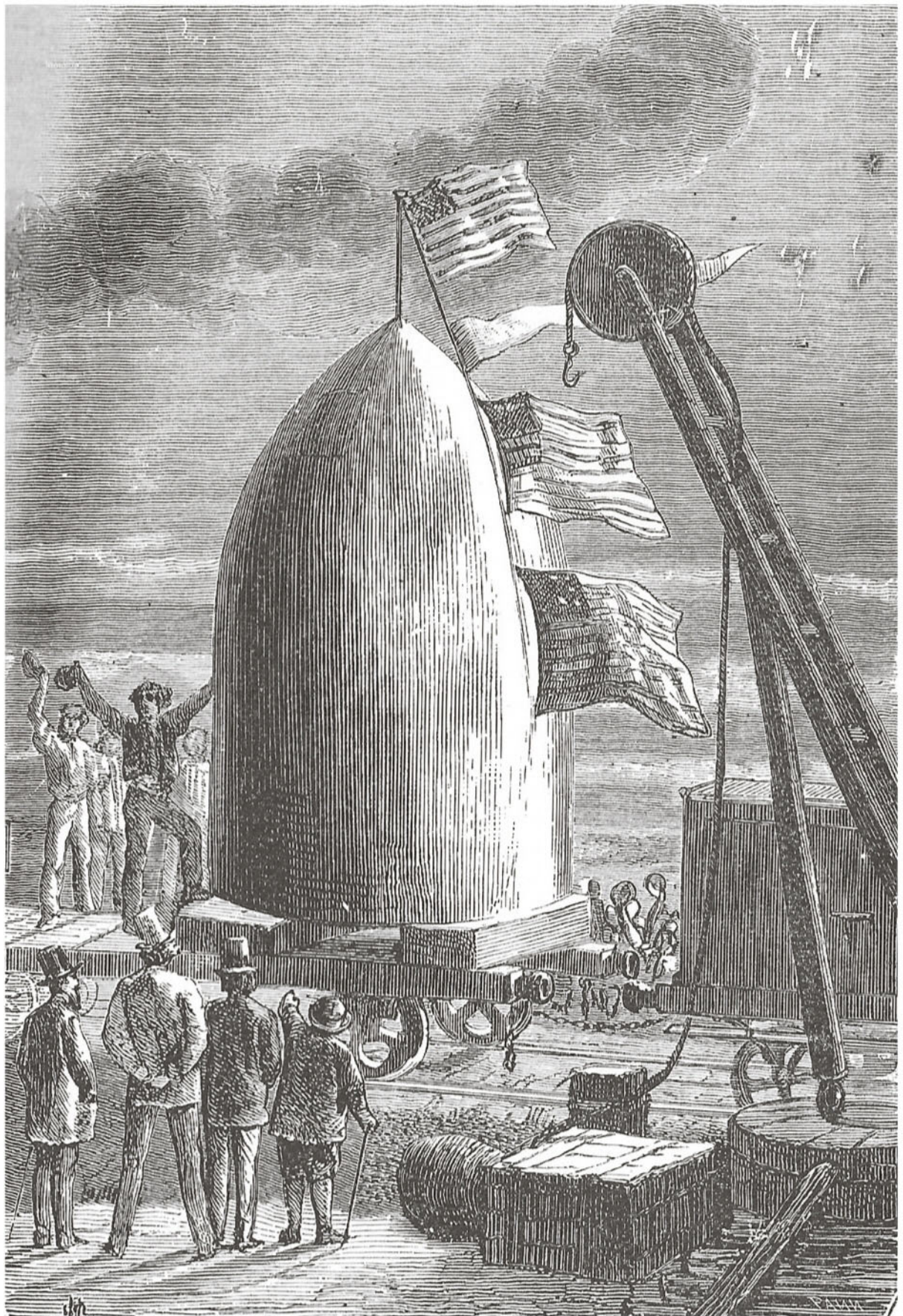
world," he says. He proposes to shoot a cannonball at the Moon — and to hit it. After rousing applause he states, "I have the honor, my brave colleagues, to propose a trial of this little experiment."

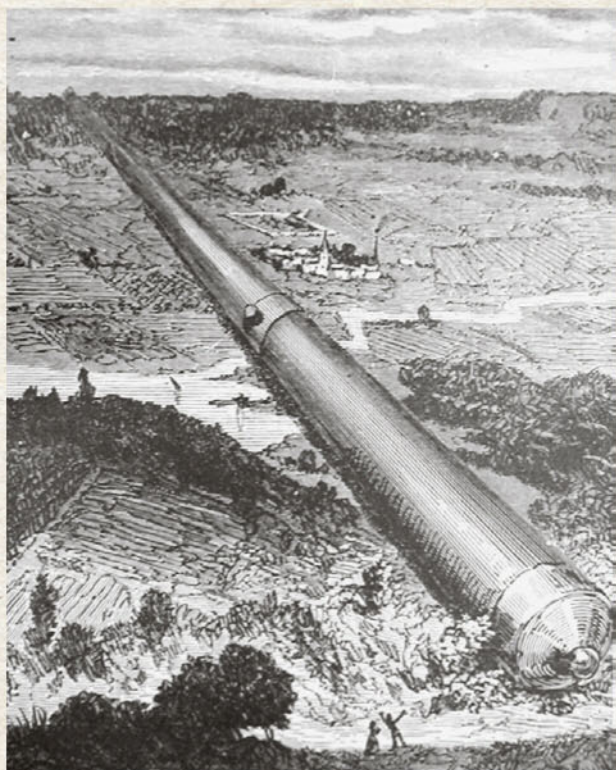
With worldwide financial, moral and spiritual support, the experiment begins. In order to reach the Moon, members of the Gun Club must build a monstrous cannon. They intend to fire it when the Moon is closest to Earth and directly overhead — something that can only occur between 28° north and 28° south latitude. After fierce lobbying (and ample name-calling) from residents of Texas and Florida, Barbicane selects Tampa Town, Florida, as the project's base of operations. Soon the artillerymen construct a 275-metre-long cannon, called Columbiad, and load it with a mountain of explosives.

A century later, in 1958, engineers at the nonfictional National Aeronautics and Space Administration (NASA) also determined Texas and Florida to be well suited for America's rocket launches. If a



FACING PAGE: The bullet-shaped projectile arrives at Stone's Hill, near Tampa Town in Florida. This and other engravings are reproduced from an 1886 printing of Jules Verne's *From the Earth to the Moon* and *Around the Moon* and provided by Jared Woodfill.





rocket is propelled eastward from close to the equator, the added velocity of the spinning Earth will help it more easily break free of its gravitational pull and require less fuel. NASA managers likewise chose Florida over Texas as its principal launch site for orbiting satellites and for trips to the Moon and beyond.

In Verne's 19th-century rendition, the Gun Club initially plans for an

To accelerate the projectile to high speed, the Gun Club's members build a mammoth cannon, Columbiad, that is 275 metres long.

unmanned mission. However, the inclusion of passengers is prompted by an audacious Frenchman named Michel Ardan, who arrives in Tampa Town demanding to fly in the projectile. In a typical Vernian twist, Barbicane and his rival, Captain Nicholl (an armour-plate magnate and foil to the Gun Club) agree to put aside their differences and join Ardan in a well-furnished bullet to be shot at the Moon. How they will return home is not fully discussed or detailed until they are en route.

In order to test the projectile, the Gun Club team practices with two small passengers: a cat and a squirrel. However, after the cannon fires and the ball falls back to Earth, only one emerges — the cat had feasted on the squirrel during the journey.

NASA engineers likewise tested their rockets with animals, specifically monkeys and mice, prior to launching human passengers. By then the space race was well under way, and in September 1968 (three months before Apollo 8) the Soviet Union's Zond 5 mission successfully flew a unique combination of tortoises, mealworms, flies, bacteria, plants and seeds around the Moon and returned them safely to Earth.

Back in Tampa Town, it is launch day. Five million visitors have flooded into central Florida to witness the momentous event, which has to occur precisely at 10:48:40pm. The three explorers descend into the cannon

and board their projectile. As the blastoff approaches, some in the crowd count up: "... thirty-eight! – thirty-nine! – forty! FIRE!!!"

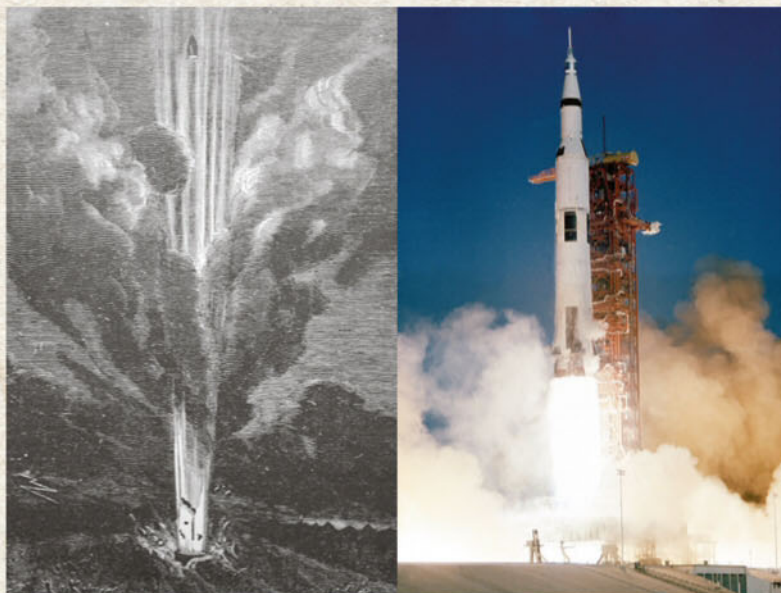
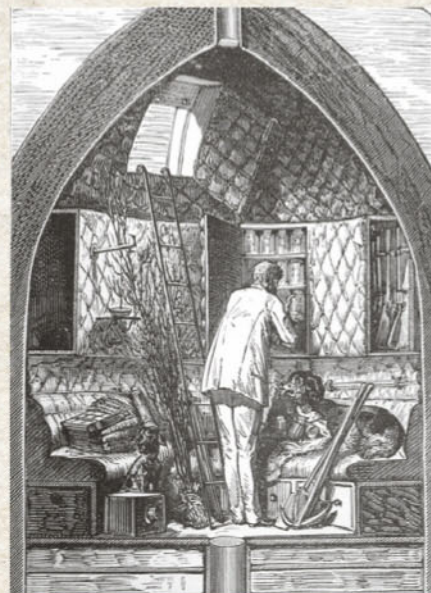
Frankly, anyone shot out of such a cannon would be instantly killed. Verne knew this, and so he explains how the shock would be dampened with compartments of water. In truth, this would not have protected the astronauts. However, in the novel, the abrupt liftoff merely knocks the trio unconscious — though it kills one of the two dogs aboard (yes, they brought dogs).

When the crew regains consciousness, they reorganise their vessel and risk opening a porthole to dispose of the unlucky canine — which then tragically drifts next to them throughout the journey. In the novel, this open-door gamble works tremendously well, but in reality the extremely low pressure of space would suck the crew from the projectile.

Earth's second moon

Once above Earth's atmosphere, the crew faces a new crisis: a giant boulder hurtles into view. It narrowly misses their tiny craft but leaves the crew shaken. What was that thing? Barbicane concludes that it was Earth's second Moon.

In the mid-19th century, planet hunting had become all the rage. The discovery of Neptune in 1846 let loose a mob of astronomers claiming the existence of new, unseen celestial



Far left: The projectile's interior is well appointed, with room for its crew of three and several animals. A bed of water under a wooden floor cushions the passengers during launch.

Left: The liftoffs of Verne's fictional spaceship and of Apollo 8 both occurred in Florida.

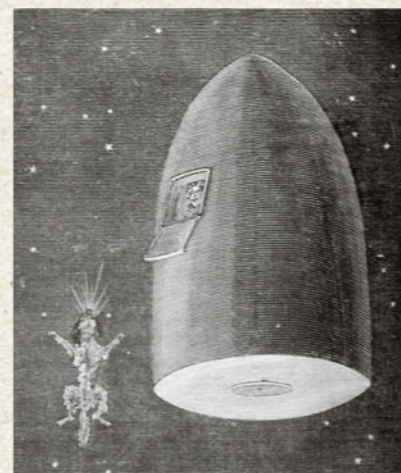
bodies. Also in 1846, French astronomer Frédéric Petit claimed that two of his countrymen had observed Earth's second moon. Based on their accounts, Petit calculated its orbit and published his findings in 1861. Verne read this theory and seized upon it as a plot device in this novel. Barbicane even cites Petit as his source! (With 150 years of hindsight, however, Earth's second moon remains pure fiction.)

As Barbicane, Nicholl and Ardan approach the Moon, they describe their observations of the lunar landscape in great detail. They spy deep craters and towering mountain

// In the 19th century, scientists believed that volcanoes had formed the craters on the Moon. The Apollo missions ultimately dashed any lingering faith in the volcano theory. //



Freed of Earth's gravity, the three passengers and assorted animals float freely as the spacecraft coasts toward the Moon.



The force of the launch kills Satellite, one of two dogs aboard. So the passengers open a hatch to dispose of it. But the carcass floats alongside the craft en route to the Moon.

peaks, radiating rays of debris, dark seas of rock and deep rifts. The travellers then notice something is amiss: the projectile will not land on the lunar surface as planned but instead carry them to within a few kilometres of the Moon's north pole.

What had gone wrong — their maths, aim or velocity? It was that wayward rock, that 'second moon,' whose proximity and gravitational pull perturbed the course of the projectile. As the explorers realise this failure, they pass over the pole and are plunged into utter darkness.

The farside (and dark side) of the Moon

The Moon is tidally locked to Earth. Therefore, from here we can only ever view one hemisphere of its surface. Not until 1959 did a robotic Soviet spacecraft, Luna 3, provide the first crude images of the unseen farside.

So what spectacular images would Verne dream up about the farside of the Moon — visions that would not be challenged for almost 100 years? Until this point of the story, Verne's descriptions were based on known science; however, the lunar farside was a great unknown in the 19th century.

The projectile reaches the Moon when it appears full from Earth, so the farside is almost pitch black. Ardan expresses his disappointment: "Here is, however, a good opportunity lost of observing the other side of the moon." Yet it is not a complete loss. The warm glow from an erupting volcano illuminates its surroundings and gives

the travellers tantalising views of this terra incognita.

In the 19th century, scientists believed that volcanoes had formed the craters on the Moon. Earth's volcanoes resembled the lunar surface from afar, and therefore geologists imagined innumerable volcanoes as the source of lunar craters. Verne's knowledge of current geological theories surely satisfied his science-minded followers.

The Apollo missions ultimately dashed any lingering confidence in the volcano theory. Samples collected by its astronauts, along with spectrographic data from orbiting craft, prove that high-velocity impacts formed the vast majority of lunar craters. There are no active volcanoes on the Moon, though eruptions shaped the topography in the distant past. The large, dark, characteristically circular maria are in fact vast lava plains that partially filled basins excavated by titanic impacts. Billions of years later, these lava 'seas' made ideal landing pads for the six Apollo missions that reached the lunar surface.

As Verne's astronauts continue around the farside of the Moon, a meteor streaks below them and explodes above the surface. The fireball brightens the lunar landscape momentarily, and the travellers are able to decipher what appear to be clouds, continents, seas and forests. During the journey, Verne cites many scientists of the day who debated the existence of a lunar atmosphere. The three astronauts



While coasting in darkness over the lunar farside (left), the passengers endure extreme cold inside their capsule. But they warm quickly (right) once the capsule returns to sunlight.

continue that debate and wonder if it was merely an illusion.

As it rounds the south pole, the projectile emerges into daylight. The travellers then observe the bleak, scarred landscape of the Moon's southern hemisphere. They see,

"Nothing belonging to a living world — everything to a dead world, where avalanches, rolling from the summits of the mountains, would disperse noiselessly at the bottom of the abyss. . . In any case it was the image of death, without its being possible to even say

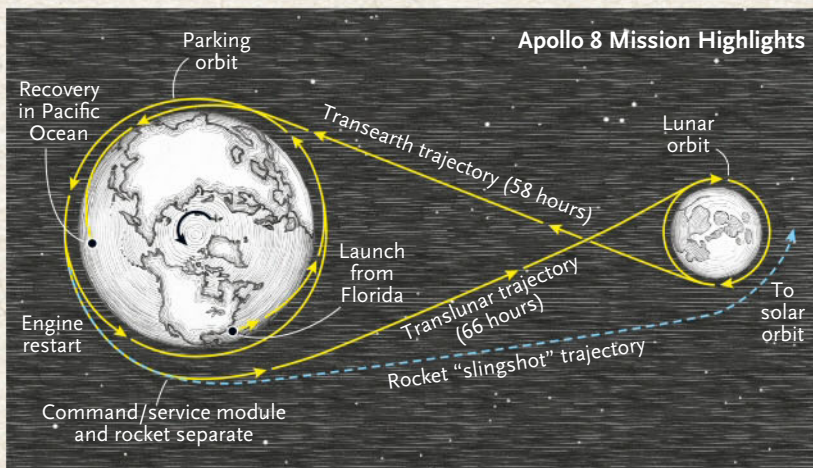
that life had ever existed there."

Buzz Aldrin, who in July 1969 became the second astronaut to walk on the Moon, expressed his awe and wonder about the beautiful but barren lunar landscape, calling it 'magnificent desolation'.

The inertia of Columbiad's projectile then carries the crew away from the Moon and returns them to Earth. The projectile streaks through the atmosphere like a shooting star and splashes into the Pacific Ocean. The Gun Club frantically scours the seafloor but later simply finds the projectile bobbing atop the waves, an American flag flapping from the top of its cone. The astronauts have returned safely!

Visions of the future

The exciting circumlunar journey not only brings fame to the three explorers but also emboldens American scientists and engineers. Verne writes, "Since Barbican's attempt, nothing seemed impossible



Apollo 8's December 1968 flight to the Moon and back took 6 days. Its three-man crew orbited the Moon for 20 hours at an average altitude of 110 kilometres. S&T

to the Americans?" The Gun Club helps to create the National Company of Interstellar Communication (NCIC) — a fictional forerunner of NASA — with a mandate to facilitate travel between the Earth and Moon, as well as to the planets and stars.

When founded in 1958, NASA likewise employed many former military scientists and engineers for the purely peaceful exploration of space. A decade later, NASA's Apollo team accomplished the Herculean endeavour of sending astronauts first around the Moon and then, just months later, down to its surface. It was a golden age for science and technology.

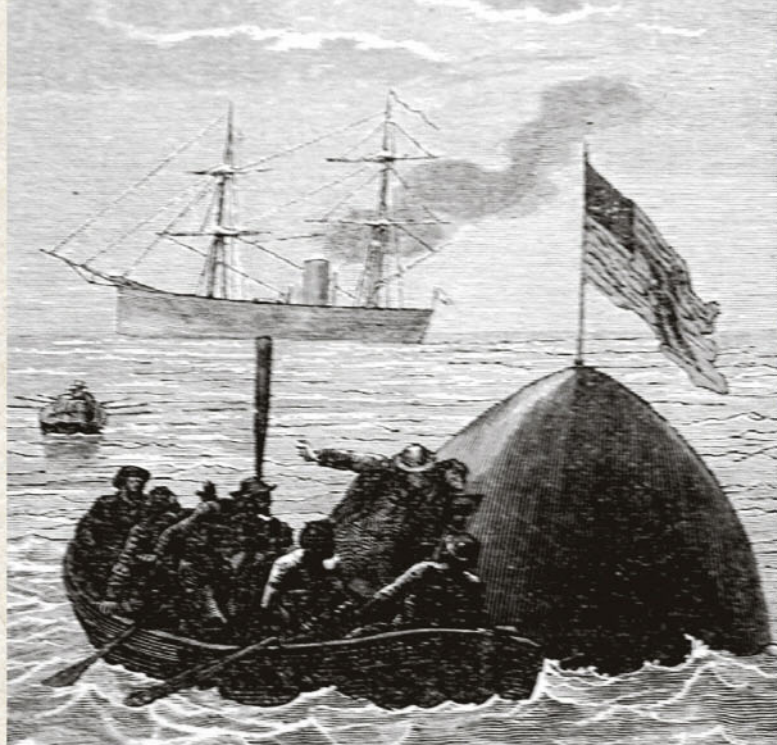
It's difficult to measure what impact the fictional writing of Jules Verne had on the real NASA missions that would follow. Surely many of the space agency's scientists, engineers and astronauts nurtured their enthusiasm for space travel as children dreaming of what must lie beyond our Earth.

Neil Armstrong certainly felt a connection to Verne's adventure story. On July 23, 1969, returning home after he and Buzz Aldrin had completed their history-making moonwalks, Armstrong began his broadcast to Earth with these words:

"A hundred years ago, Jules Verne wrote a book about a voyage to the Moon. His spaceship, Columbia [Columbiad], took off from Florida and landed in the Pacific Ocean after completing a trip to the Moon. It seems appropriate to us to share with you some of the reflections of the crew as the modern-day Columbia completes its rendezvous with the planet Earth and the same Pacific Ocean tomorrow."

Often the lines between science fiction and science fact become blurred. But, more interestingly and prosperously, they inspire each other. All new scientific discoveries are born in the imagination of dreamers. On this 150th anniversary of Jules Verne's epic journey, pick up a copy and see what you discover ♦

Dean Regas is the outreach astronomer for Cincinnati Observatory and co-host of the bite-sized astronomy program Star Gazers on US channel PBS.



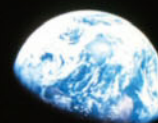
Apollo 8: Life imitates art

Verne's 1865 fictional trip around the Moon had several startling similarities to Apollo 8's circumlunar trip in December 1968. Both missions had a crew of three: Ardan, Barbicane and Nicholl in the novel; Anders, Borman and Lovell aboard Apollo 8. Verne's fictional projectile blasted off from Tampa Town, only 212 kilometres from NASA's site at Cape Canaveral. Verne's Columbiad fired its projectile at 39,500 kilometres per hour. Apollo 8 initially orbited Earth, and then rockets accelerated the capsule to 38,930 kilometres per hour toward the Moon. Neither craft had enough velocity to break free of Earth's gravitational pull; instead, both reached a point at which the Moon's gravity attracted them the rest of the way.

Verne's projectile then skimmed the lunar surface during a full Moon, which meant that Ardan, Barbicane and Nicholl could hardly see anything when looking back at the 'new' Earth. But Anders, Borman and Lovell arrived during a waxing crescent phase. Consequently, after rounding the Moon, they were able to capture the timeless image of a gibbous Earth rising over the lunar landscape.

Verne's craft ultimately landed in the Pacific Ocean and was recovered by the *Susquehanna*, a vessel from the U.S. Navy. Apollo 8's capsule likewise dropped into the Pacific Ocean (8,000 kilometres from Verne's landing spot) and was recovered by the aircraft carrier USS *Yorktown*. Both capsules were constructed of aluminium — and both floated.

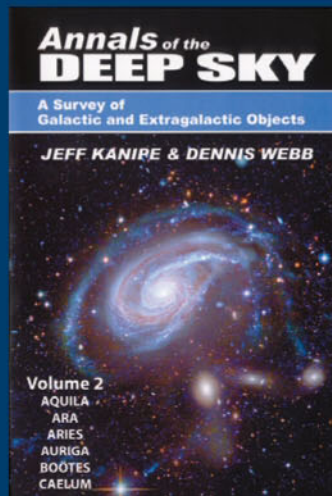
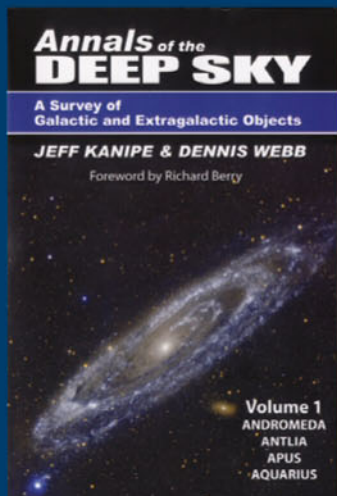
As the crew of Apollo 8 emerged from the Moon's farside, they saw a gemlike gibbous Earth rising above the bleak lunar terrain below them. NASA





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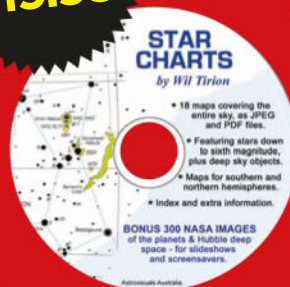
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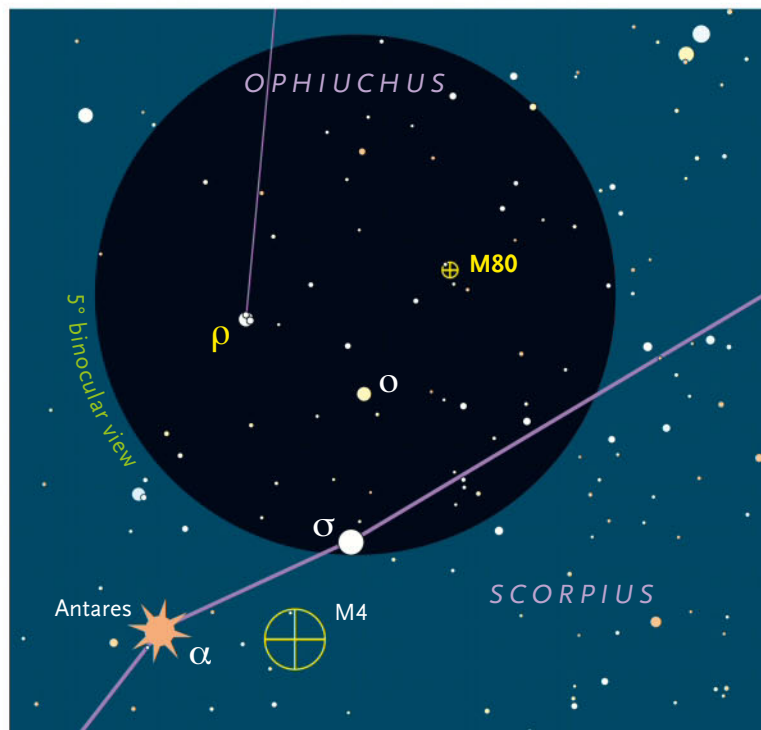
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A triple and a globular

An observing friend of mine has a particular fondness for what he calls 'pizza objects.' These are celestial two-for-one deals — a pairing of targets lying in the same field of view. Two objects for the effort of finding one. And if they're different from each other, so much the better — variety is the spice of life! So in his honour, let's enjoy a two-for-one binocular field northwest of the star Antares that gives us an easy triple star and a much more challenging globular star cluster.

The triple star is **Rho (ρ) Ophiuchi**. It might just be the most famous star you've never seen. In long-exposure photographs of the region, Rho is surrounded by a colourful fog of nebulae. Indeed, the Rho Ophiuchi Nebula is so well-known that few seem aware that Rho is also a striking binocular triple. It comprises a

5th-magnitude primary with an equidistant duo of 7th-magnitude companions forming a tidy triangle. I can easily see all three component stars with 7×35s.

Half a binocular field west of Rho, we find our bonus object, globular cluster **M80**. Most globulars are tricky at the low magnifications of typical binoculars, but M80 is doubly difficult because it's so small. What you're hunting for is something that looks like a slightly out-of-focus 7.3-magnitude star. Even with my 15×45 image-stabilised binoculars, M80 doesn't exactly jump out of the field. Fortunately, it's the brightest point of light in that spot. It also serves as the westernmost tip of a triangle that includes Rho Ophiuchi and Omicron (ο) Scorpii. M80 is one of those binocular targets that's not difficult to see but is a challenge to identify. ♦

USING THE STAR CHART

WHEN

Early August	10pm
Late August	9pm
Early September	8pm
Late September	Dusk

These are standard times.

HOW

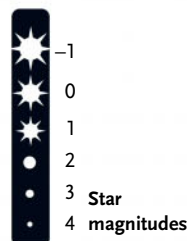
Go outside within an hour or so of a time listed above. Hold the map above your head with the bottom of the page facing south. The chart now matches the stars in your sky, with the curved edge representing the horizon and the centre of the chart being the point directly over your head (known as the zenith).

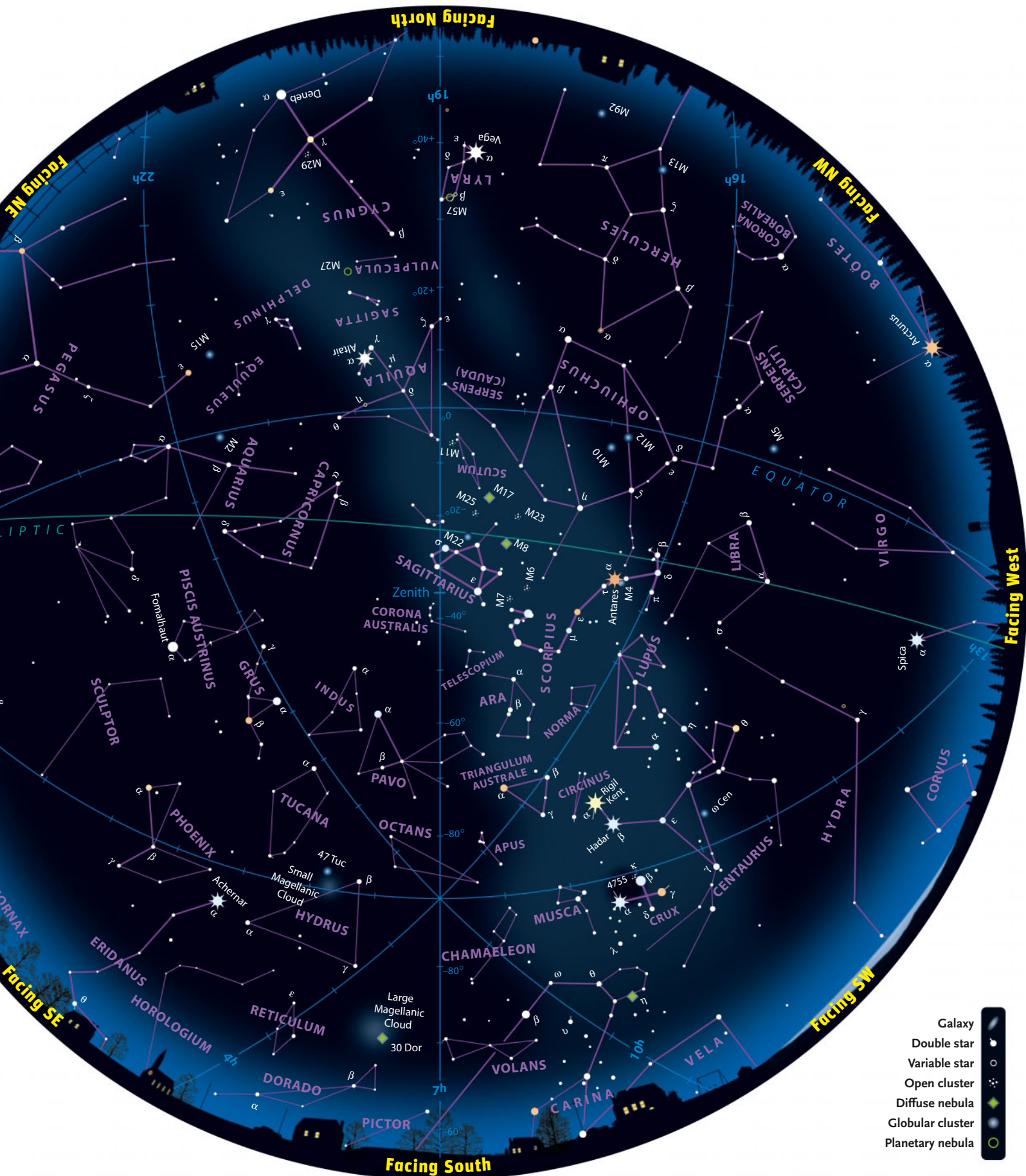
FOR EXAMPLE: Look at the chart, and you'll see that the bright star Altair in the constellation Aquila is about halfway between the northern horizon and the middle of the chart. So if you look into the northern sky, you'll find Altair about halfway between the horizon and the zenith.

NOTE: The chart is plotted for latitude 35°S (for example, Sydney, Buenos Aires, Cape Town). If you're much further north of there, stars in the northern part of the sky will be higher and those in the south lower. If you're further south, the reverse is true.

ONLINE

You can get a sky chart customised for your location at any time at SkyandTelescope.com/skychart







Stars for a moonlit night

Bright moonlight is no excuse for not getting out under the constellations



CHRIS ISHERWOOD / FLICKR / CC BY-SA 2.0

This column is normally dedicated to the stars and constellations.

But the stars do cohabit the night sky with other celestial bodies, and there's one such nighttime object that radically affects the visibility of stars. It is, of course, the Moon.

It's all about star-people versus Moon-people. This sounds like a conflict in a B-grade science-fiction movie — but the question is how do you see yourself: as a star-person or a moon-person? Do you enjoy exploring all the details of the brightest satellite in the Solar System? Or do you like to travel and revel in the starry universe?

Most of us, of course, enjoy both lunar and stellar observing. But bright moonlight can make for a frustrating experience for would-be stellar and deep sky observers. So let's get a few things straight about moonlight.

First of all, we should never begrudge it. It's just too magical — even scientifically speaking. Moonlight covers everything like the finest of meshes. But

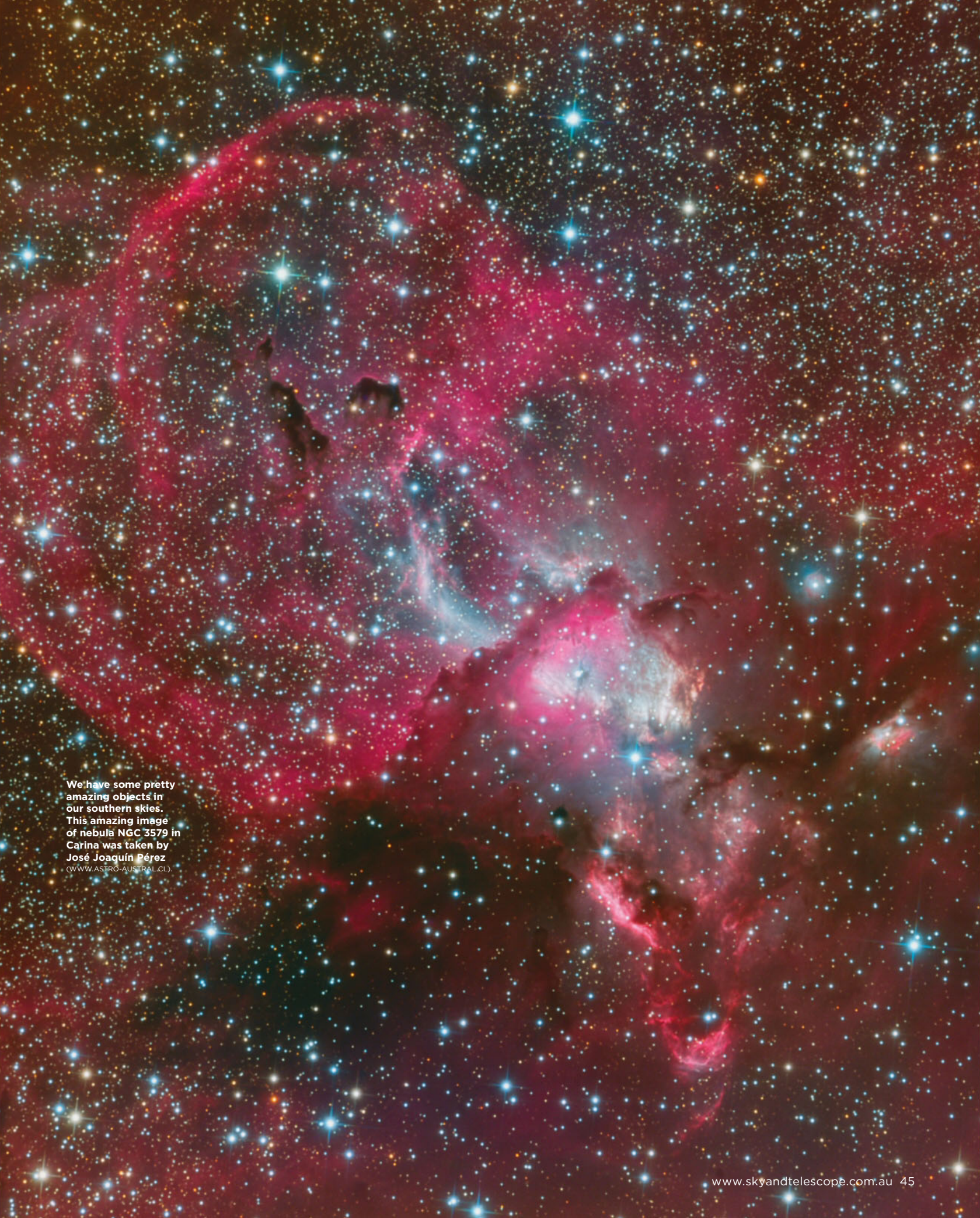
consider some of the scientific facts about this seemingly mystical radiance. A sheet of white paper under moonlight is about 2,000 times darker than black velvet in sunlight. On the other hand, the light of the full Moon is about 33,000 times brighter than Sirius. It is more than 2,000 times brighter than Venus when the planet is brightest. Full moonlight is even about 1,000 times brighter than the combined light of all the nighttime stars. And it isn't millions of times dimmer than the Sun, just 400,000 times dimmer.

But there's good news for those of us who want to do some stellar observation while the Moon is in the sky. The first quarter Moon — a half-lit Moon — isn't half as bright, but only one-eleventh as bright as the full Moon. This is due to the terminator and the many large shadows near it stretching down the Moon's central meridian at first quarter, as well as to the lack of a special kind of retro-reflecting that occurs from the lunar surface only very near full phase.

Last quarter Moon is even dimmer than first quarter due to its higher proportion of the dark maria. The lunar light is half as bright as full Moon not seven days before full (around first quarter) but a mere 2½ days before. This explains why observations of the stars and even extended deep sky objects through telescopes are not as compromised by most phases of the Moon as people expect.

A lesson can be learned from meteor observers. They simply watch for meteors in a direction away from the Moon or, if the Moon is especially bright, they might block the direct moonlight with a tree, building... or even an umbrella. So when it's raining moonlight (the grand Mare Imbrium is 'the Sea of Rains' after all), why not use an umbrella or parasol — or would it be called a paralune? ♦

Fred Schaaf welcomes your comments at fschaaf@aol.com.



We have some pretty
amazing objects in
our southern skies.
This amazing image
of nebula NGC 3579 in
Carina was taken by
José Joaquín Pérez
(WWW.ASTRO-AUSTRAL.CL).



An evening gathering

Three planets and a star will grace our western skies

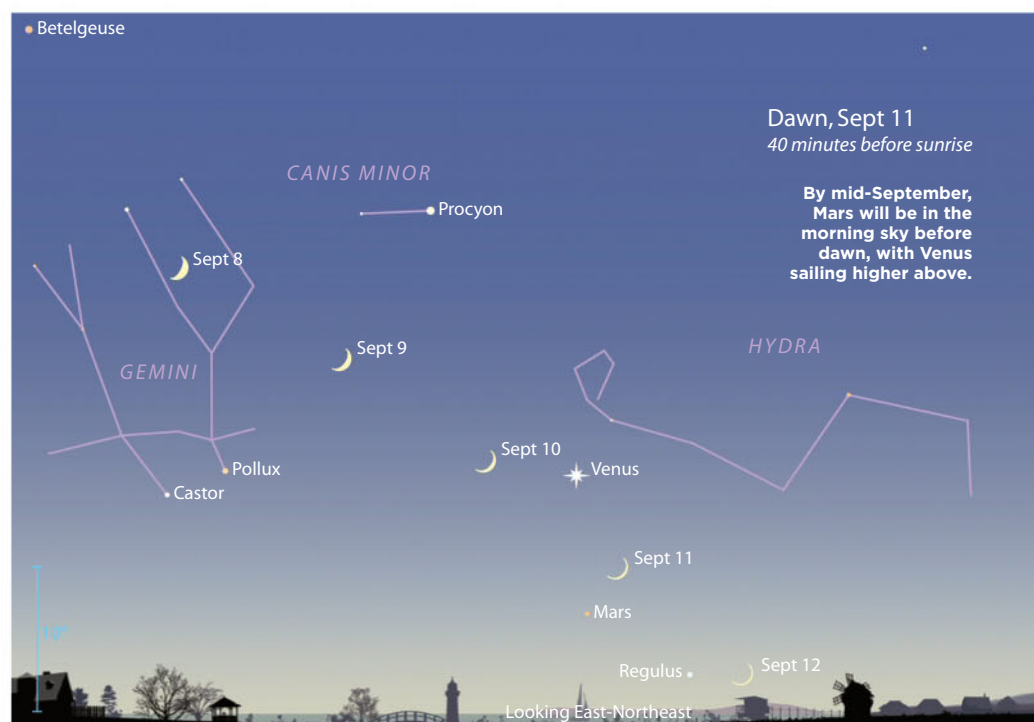
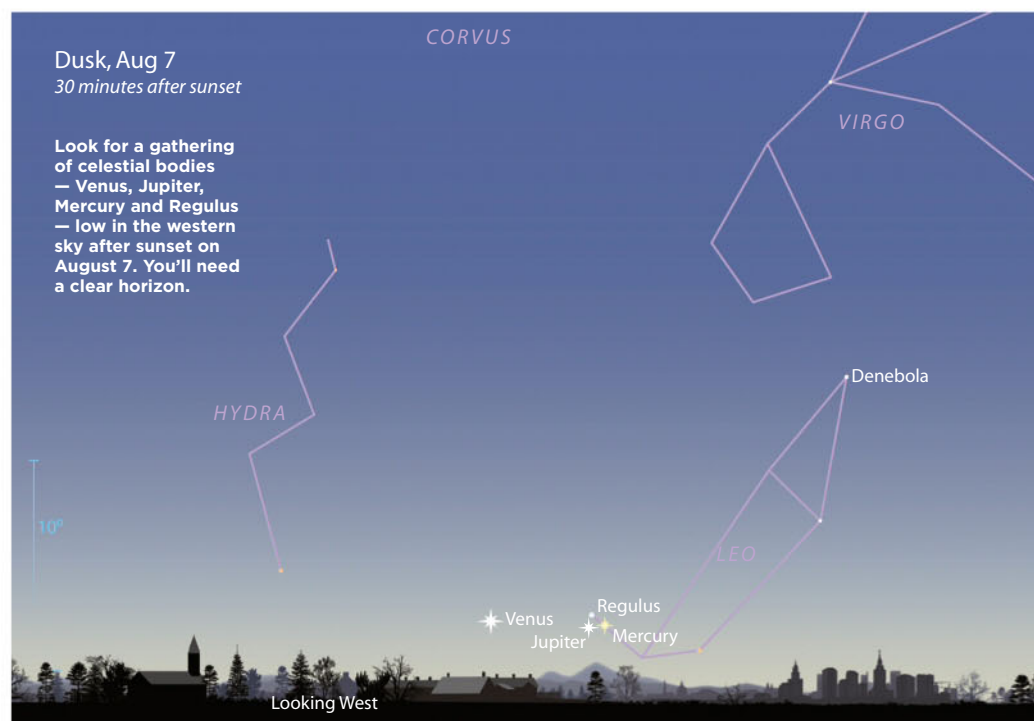
Mercury returns to our evening skies in August, low down on the western horizon but slowly climbing higher as the month progresses. And it won't be alone – Jupiter and Venus will be nearby, as will the star Regulus on August 7 and the crescent Moon on the 16th. Moving into September, Mercury will appear close to the star Spica, before sliding back down towards the horizon and the Sun's glare. Look for the Moon nearby on September 15.

As mentioned, **Venus** will be low on the western horizon after sunset at the beginning of August, but will be lost in the glare of the Sun by mid-month as it slides between us and our star. But don't worry, it will be back at the end of the month, this time on the eastern horizon in the hours before dawn. Thereafter, it will be visible all through September – look for the Moon nearby on the 10th.

Mars was too close to the Sun for observation during July, but will return to our eastern, morning skies in August. Initially remaining close to the horizon and embedded in the dawn light, it will rise higher as the weeks progress and by September will be more easily visible. The Red Planet will appear to pass right through M44 – an open star cluster, also known as the Beehive Cluster – on August 20 and 21. Get out your binoculars and take a look. And then also keep an eye out for the planet as it comes near to the star Regulus from September 24 to 26. The reddish Mars and blue star will make a fine contrast.

Jupiter begins August low on the western horizon, in company with Venus and Mercury. Like Venus, Jupiter too will soon sink toward the horizon as the days pass, and be lost in the Sun's glare by mid-month. Watch for the triangle made by Jupiter, Mercury and the star Regulus on August 7. Jupiter will reappear to the east in the morning sky in late September, joining Mars and Venus by month's end.

Saturn is well placed for evening viewing during August and September, reaching quadrature – where the angle between Sun, Earth and Saturn is 90 degrees – on August 22. This means that it will be at its highest point in the



northern sky as the Sun is setting. Watch for the Moon nearby that same night, and again on September 19.

And finally, **Earth** will reach the spring

equinox on September 23, a day on which the hours of daylight and darkness are more or less equal. The equinox is also a sign that summer is on its way.

Events Of Note

Aug	1	Jupiter 6° north of Venus
	7	Jupiter 0.6° south of Mercury
	7/8	Mercury 1° north of Regulus
	9	Aldebaran 0.7° south of the Moon
	13	Mars 6° north of the Moon
	16/17	Mercury 2° north of the Moon
	20	Spica 4° south of the Moon
	21	Mars 0.2° south of Beehive Cluster
	23	Saturn 3° south of the Moon
	23	Antares 10° south of the Moon
	29	Mars 9° north of Venus
Sept	5	Aldebaran 0.6° south of the Moon
	10	Venus 3° south of the Moon
	11	Mars 5° north of the Moon
	11/12	Regulus 3° north of the Moon
	15	Mercury 5° south of the Moon
	16	Spica 4° south of the Moon
	19	Saturn 3° south of the Moon
	20	Antares 10° south of the Moon
	23	Spring equinox, 6pm AEST
	25	Mars 0.8° north of Regulus

Times are listed in Australian Eastern Standard Time



August 2015

Phases

Last Quarter August 7, 02:03 UT
 New Moon August 15, 02:53 UT
 First Quarter August 22, 19:31 UT
 Full Moon August 29, 18:35 UT

Distances

Perigee August 2, 10h UT
 362,139 km
 Apogee August 18, 01h UT
 405,848 km
 Perigee August 30, 15h UT
 362,139 km

September 2015

Phases

Last Quarter September 5, 09:54 UT
 New Moon September 13, 06:41 UT
 First Quarter September 21, 08:59 UT
 Full Moon September 28, 02:51 UT

Distances

Apogee September 14, 11h UT
 406,464 km
 Perigee September 28, 00h UT
 356,877 km



This composite image of the Milky Way and a formation in the Mungo National Park in NSW, was taken by Damien Seidel. He used a Nikon D810 with a Samyang 14mm f/2.8 lens.



Return to Sagittarius

Sweeping up doubles in south-west Sagittarius

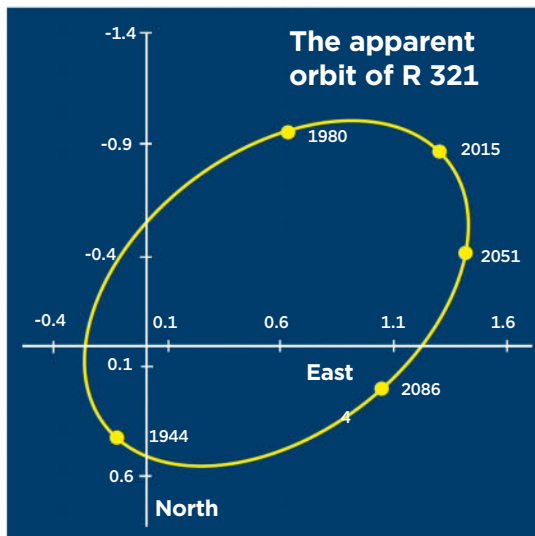
This issue's doubles are in the southwest corner of Sagittarius, and not near the Milky Way. With no bright guide stars and only a few stars of 4th and 5th magnitude, the use of Go To systems, or setting circles, makes for easier finding than star-hopping. Even so, our targets can be found with optical finders of 50-mm and a good star map. All of them are 19th century discoveries, four of them by John Herschel from his southern sky survey of the 1830s.

Starting with the most northerly, the attractive multiple star **HJ 5188** (old-style, h 5188) is a John Herschel discovery from 1834. An 18-cm refractor at 100× showed a bright white star (A) with a well-separated magnitude-7.5 companion (C), and a much closer magnitude-10 star north-east (B); wide north-east was a little 10th-magnitude pair (DE). Altogether a fine effect. Ernst Hartung in his classic book *Astronomical Objects for Southern Telescopes*, says all this is visible with 7.5-cm; I'd suggest more aperture is better. Hartung mentions a reddish star 5' north-west that contrasts nicely with the white A and C stars.

Some 5 degrees south-southwest from HJ 5188 is **HJ 5178**, of 7th and 8th magnitudes at nearly 3" separation, visible with an 8-cm telescope. The 18-cm refractor showed a somewhat uneven deep yellow pair, nicely seen at 135×. Little changed over time and, with similar proper motions, this is likely a binary with a very long-period orbit.

From HJ 5178, two degrees north-east is the 8th-magnitude pair **STN 64**, discovered by Ormond Stone with the 28-cm refractor of the Cincinnati Observatory. It's been closing slowly since discovery; the 18-cm refractor showed a tight yellow pair at 100× that was easy at 180×. Another long-period binary, it will be many years before the orbit can be calculated.

Some 2 degrees north-west from HJ 5178 is one of this month's test objects for larger telescopes. **SEE 404** was discovered by T.J.J. See in 1897, since when the position angle has increased, with little change in separation. In 1991, the Hipparcos satellite measured the



separation as just 0.63" — the brightness difference of the stars, magnitudes 6.6 and 9, makes it more difficult still. The current separation appears similar to 1991, and this fits the Rayleigh Criterion for 22-cm aperture; optimists might try it with that aperture. Around 28- to 30-cm aperture will place the secondary star right on the first diffraction ring, making it very difficult. I'd suggest 32-cm and larger scopes in good seeing for this one. There's also a wide dim companion, south of the primary.

Continuing southwards, 4 degrees south-east from HJ 5178 is the changing



Several of the double stars covered this month were identified in the 1830s by John Herschel.

binary **R 321**, an 1880 discovery by H.C. Russell at the Sydney Observatory using its 29-cm refractor. These days R 321 is wider than in 1880. With an 18-cm refractor, it was a bright orange star, not quite single at 100×, in a field with lesser stars in lines and triangles. Increasing the power to 180× neatly separated the stars, showing a close, moderately uneven pair; a fine object.

A preliminary orbit calculation gives the period as nearly 180 years. The separation had decreased to a minimum around 1950, with a gradual increase since then, and it's now approaching the maximum of 1.6" around 2026, after which there will be a slow decrease for a hundred years. R 321 is about 120 light-years away; the orbit, in projection, has a maximum size about 60 a.u. — twice the distance from the Sun to Neptune.

From R 321, just over 1 degree west-northwest is **HJ 5189**. Its stars are of 8th and 9th magnitude, at an easy separation, and 8-cm will show it, though more aperture improves the effect. It looked better than the numbers suggest — with 18-cm at 100× it is a neat little pair, placed between two 9th-magnitude stars. With 35-cm both stars appear yellowish.

From R 321, 3-plus degrees south-west is the easy pair **DUN 230**, a fairly

Selected double stars in Sagittarius

Star Name	R. A. hh mm	Dec. ° ' "	Magnitudes	Separation (arcseconds)	Position Angle(°)	Date of Measure	Spectrum
SEE 404	20 05.5	-33 00	AB 6.6, 9.0	0.6"	109	1991	B4III
"	"	"	AC 6.6, 12.6	21.7"	186	2010	
HJ 5178	20 13.7	-34 07	7.1, 8.2	2.8"	009	1991	K1/2III
STN 64	20 16.9	-32 36	8.1, 8.5	1.7"	296	2008	G5V
DUN 230	20 17.8	-40 11	7.4, 7.7	9.9"	112	2010	F8
HJ 5188	20 20.5	-29 12	AB 6.7, 10.1	3.6"	042	1998	A2III
"	"	"	AC 6.7, 7.6	27.2"	320	2010	A2III, A1
"	"	"	AD 6.7, 10.0	120"	038	1999	
"	"	"	DE 10.0, 10.0	4.7"	186	1999	F0V
HJ 5189	20 21.8	-36 54	8.8, 9.6	7.5"	294	1998	F6V, G5
BU 763 (Kappa-2)	20 23.9	-42 25	5.7, 7.3	0.3"	345	2013	A5V
R 321	20 26.9	-37 24	6.6, 8.1	1.6"	126	2013	K2IV, K1V

Data from the *Washington Double Star Catalog*

bright yellowish double in a field with a scattering of 9th- and 10th-magnitude stars. This is a neat double accessible to small scopes; the separation has become closer since James Dunlop found it in the 1820s. Common proper motion of the stars suggests it is a long-period binary.

To end, the ultra-close bright pair **Kappa-2 Sagittarii, BU 763**. Discovered by Sherburne Wesley Burnham using a 15-cm refractor, by 1960 when Hartung observed it the pair was closing, and he noted: "15cm showed the stars in contact with dark line

between, and 20cm was needed to separate them..." It closed to a minimum of 0.3" around 2000, and is now slowly widening, though at present is still only 0.4"; I'd suggest apertures of 30-cm or more. A preliminary orbit with a period of 700 years has been calculated, suggesting that 200 years from now it will be an easy pair at a separation of 2.8". ♦

Ross Gould has been a long-time observer from the suburban skies of Canberra. He can be reached at rgould1792@optusnet.com



Celestial Calendar

Alan Plummer

The rise of RU Sagittarii

Watch this Mira-type variable appear out of the darkness

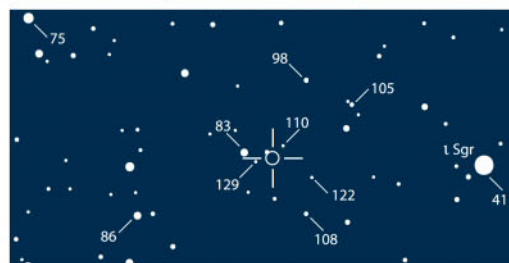
We've got a challenging, and hopefully satisfying, target this month: RU Sagittarii.

A Mira-type pulsating variable star, RU Sag has a period of 240.49 days (although this is known to vary a little) and a spectral class of M3e-M6e.

Although RU Sag's maximum light (6th magnitude) is not predicted to occur until October 11, as this issue comes out it should have risen past 11th magnitude.

At first, unless you use a telescope of 15-cm aperture or more, you'll most likely be logging negative observations — in other words, it will be fainter than the faintest star you can see. But no matter what instrument you have — whether binoculars, a 100mm refractor, or a bigger light bucket — keep watching RU Sag's field night after night and eventually you'll see the star begin to appear out of the darkness (although make sure you're not confused by the 10th-magnitude companion star close to the north-east.)

It's always worth a reminder of why we amateurs make these observations. No professional astronomer can hope to watch all of the catalogued variable stars, so they rely on dedicated amateurs to help them out by making visual observations. Automated surveys are good but some stars, including RU Sagittarii, have visual data sets going back more than a century, and continuity and



HOW TO FIND RU SAGITTARII North is to the top in these charts, which come courtesy of the AAVSO. The large-scale chart is approximately 5 degrees from north to south, while the small scale chart is approximately 1 degree from north to south. RU Sgr is located at (J2000) 19h 58m 42.87s, -41° 50' 57.9".

consistency of data and observing methods are invaluable. And, not the least, having an eye at the eyepiece is often useful for spotting the unexpected! ♦

Alan Plummer observes from the Blue Mountains west of Sydney, and can be contacted on alan.plummer@variablestarssouth.org



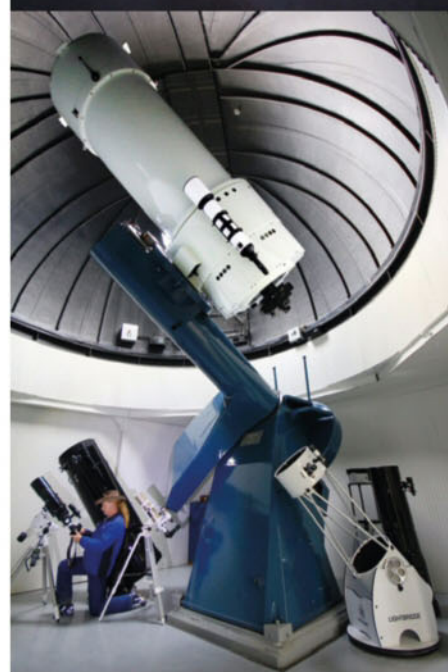
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Four comets to find

David Seargent

Several comets, some hard, some easy, are on show for southern observers

With the 'Rosetta comet' **67P/Churyumov-Gerasimenko** reaching perihelion on August 13 at 1.24 a.u. from the Sun, the attention of comet enthusiasts during this period is likely to be concentrated on the Internet rather than the night sky. The comet itself will be low in the morning twilight for Southern Hemisphere observers and, although magnitude predictions differ, it will not be an easy visual object for small telescopes.

Churyumov-Gerasimenko is unlikely to be much brighter than 13th-magnitude or thereabouts (although some predictions are a little more optimistic) and this, coupled with its small elongation angle from the Sun and early morning appearance, will not make it a suitable object to show the general public at field nights.

After passing perihelion at just 0.31 a.u. on July 6, **C/2014 Q1 (PANSTARRS)** should still be visible low in the evening sky during the first half of August. Crossing from Sextans into Crater during the first week of that month, this comet will reach Hydra around the middle of August as it continues to sink into the western sky. Assuming that it survives its close encounter with the Sun in July, it may still be around magnitude 8.5 as August begins, but is expected to fade quite rapidly to around 10 as it sinks into the western twilight mid-month.

Also mentioned in the previous issue, **C/2013 US10 (Catalina)** is likely to be around magnitude 9 at the start of August and will be well placed for southern observers during the months of August and September. It will be circumpolar from mid-southern

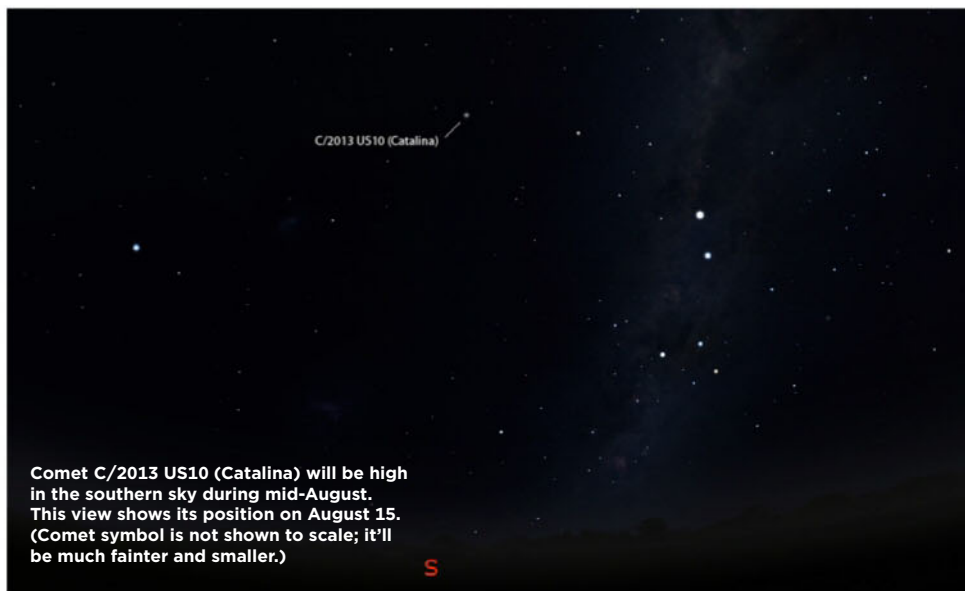
latitudes for much of this time and will stay within 20 degrees of the south celestial pole from August 7 until August 21.

At the end of August, the comet will be located in Triangulum Australis, moving into Lupus where it spends most of September until crossing into Centaurus during the last week of that month. If the comet brightens as expected, it should be around magnitude 7 to 7.5 by the end of September and readily visible through ordinary binoculars.

Another comet which may be of visual interest, especially to more northerly placed observers, is **C/2015 F4 (Jacques)**. This object was discovered by C. Jacques on CCD images taken using the 0.28-m astrograph at the

SONEAR Observatory at Oliveira (Brazil) on March 27 this year. At that time, it was estimated to be magnitude 16. It will reach perihelion on August 9 at 1.7 a.u. from the Sun and will be visible during August and September in the region of Vulpecula/Hercules/Lyra. Unfortunately, current magnitude estimates indicate that it will remain rather faint — in the magnitude 12 or 13 range — but as these predictions are based on CCD estimates, there is a possibility that it may become somewhat brighter than this. ♦

*David Seargent's latest book on comets, **Snowballs in the Furnace**, is available as a paperback-on-demand from Amazon.com*



Comet **C/2013 US10 (Catalina)** will be high in the southern sky during mid-August. This view shows its position on August 15. (Comet symbol is not shown to scale; it'll be much fainter and smaller.)

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Small Sagittarius Star Cloud

The Sagittarius Milky Way is home to fascinating dark nebulae and open clusters

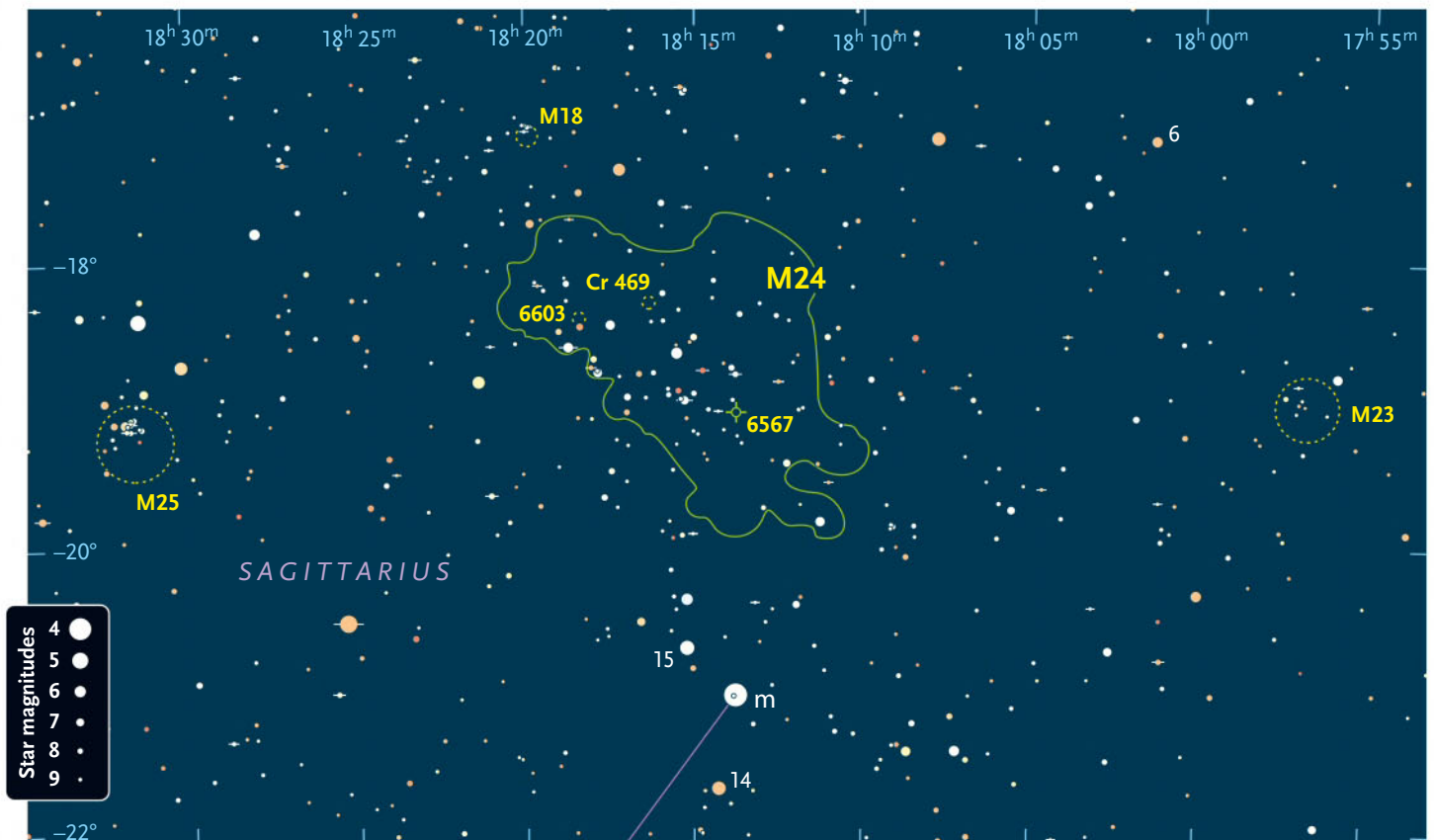
On moonless nights away from the glow of outdoor lighting, the misty trail of the Milky Way stretches across the sky through Sagittarius. Its gossamer glow is fashioned from remote swarms of innumerable stars, and the silvery splendour of their intermingled light shows us the plane of the disk-shaped, spiral galaxy in which we live. For the most part, the stars that lie along this section of the Milky Way, as well as the dark clouds that decorate it, lie within the Sagittarius-Carina Arm of our galaxy. This is the next spiral arm inward from ours, and it blocks the view beyond. The Sagittarius Milky Way is interlaced with dark rifts, however. Within one dark rift, a gap allows us to peer deeper into the galaxy. The stars that shine through

this hole make up **Messier 24**, the Small Sagittarius Star Cloud.

Messier 24 is sometimes called Delle Caustiche, a name attributed to the 19th-century Italian astronomer Angelo Secchi. However, Secchi made it clear in his 1877 book *Le Stelle* that he was only describing a small part of M24. He writes of a little cloud, less than half the Moon's apparent diameter, made up of a multitude of separate groups of tiny stars. Two of these groups are charted as seen through a 9.6-inch telescope. The first is labeled 'Gruppo delle Caustiche' (Group of Caustics), because its diminutive stars are arrayed in arcs that resemble caustic curves (such as are formed when sunlight shines through a drinking glass). Secchi describes the second group, close

south of the first, as a circular collection of beautiful starlets arranged in several rays diverging from its brightest star. Its chart is labeled 'Gruppo a raggera' (Sunburst Group). He refers to yet another section, next to the Sunburst, as a magnificent system of crossed arcs, the middle strewn with faint stars too numerous to count.

Indeed, one can't help but point a telescope anywhere within the $2^\circ \times 1^\circ$ oblong of M24 without being struck by the richness and variety of the star fields. Through my 130-mm refractor with a wide-angle eyepiece at 23 $\times$, M24 spans most of the field of view. Its best-known features are the dark nebulae **Barnard 92** and **Barnard 93**, seen in projection against the cloud like dusky eyes in a fuzzy face. B92 is a nearly north-



south ink spot covering about $13.5' \times 8'$. B93 is an $8' \times 3'$ band with a less pronounced extension bending southward from its southwestern end. This eye seems to be winking.

Collinder 469 is a little knot of stars just a few arcminutes off the extension's end. A very long and distinctive line of faint stars sweeps east-northeast to west-southwest across M24. The star chain skims north of B92 and B93, and it has a northward bump between them.

The open cluster **NGC 6603** is a nicely obvious patch of haze flecked with a few superimposed stars. It's perched near a red-orange star, which is the middle star in the northern arm of a $20'$ 'V' of 7th- and 8th-magnitude stars. The middle star in the southern arm of the 'V' is the double **SHJ 264** (S,h 264). Its whitish components are well separated, with the 7.6-magnitude companion $17''$ northeast of its 6.9-magnitude primary. The pair's designation tells us that it's the 264th entry in James South's and John Herschel's multiple star catalogue of 1824.

Although I can't fit all of M24 in the field of view at $63\times$, it's amazing

how much more obvious and intricate the dark nebulae are at this magnification. A fairly conspicuous thread runs east-northeast from B93, leading to a large area of patchy darkness that contains **Barnard 307**. Much dark nebulosity spreads west from B92, and a long, forked patch (**Barnard 304**) reaches southwest. Collinder 469 and NGC 6603 share a field of view. Cr 469 shows six stars that form a capital 'A' pointing northeast, while pretty NGC 6603 is a granular patch of mist. At $117\times$, Cr 469 displays 11 stars in a group whose longest dimension is about $3.25'$. A bit larger but much more crowded, NGC 6603 is sprinkled with many faint- to very-faint stars over haze. It sports a prominent southeast-northwest band of stars that cuts across the cluster's centre.

NGC 6603 is wonderfully transformed by a 25-cm scope. At $213\times$, it's a beautiful cluster of myriad diamond-dust stars, with little unresolved haze remaining.

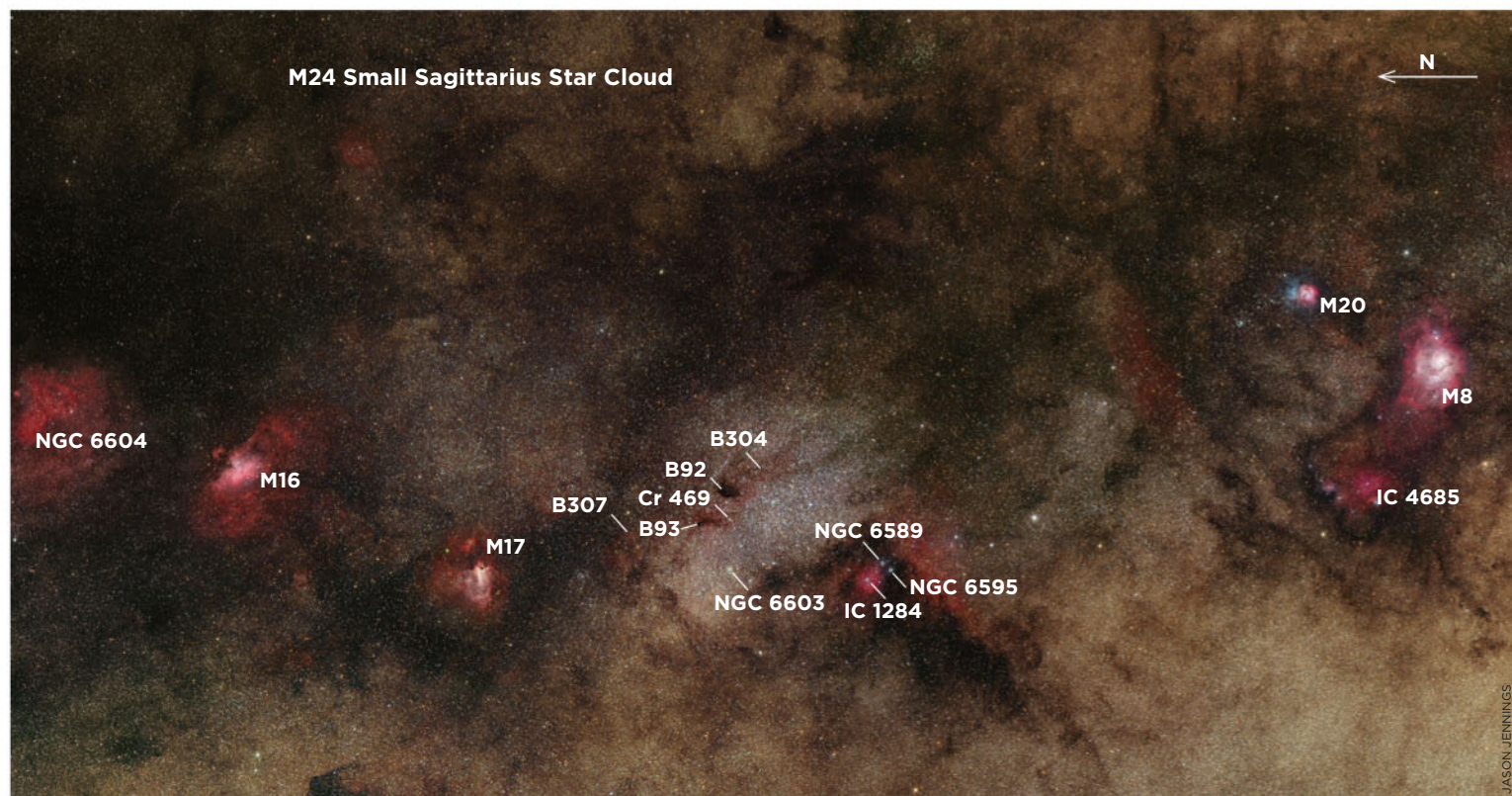
You might think that M24 would be a terrible place to look for a petite planetary nebula, but I was surprised to find **NGC 6567** reasonably easy to

spot through my 130-mm scope. At $37\times$ it appears bluish and minuscule, but most definitely not stellar. A magnification of $117\times$ reveals a tiny blue-grey disk that's fairly bright. A dim star sits just off the nebula's eastern side. At $205\times$ the nebula seems to have a brighter centre.

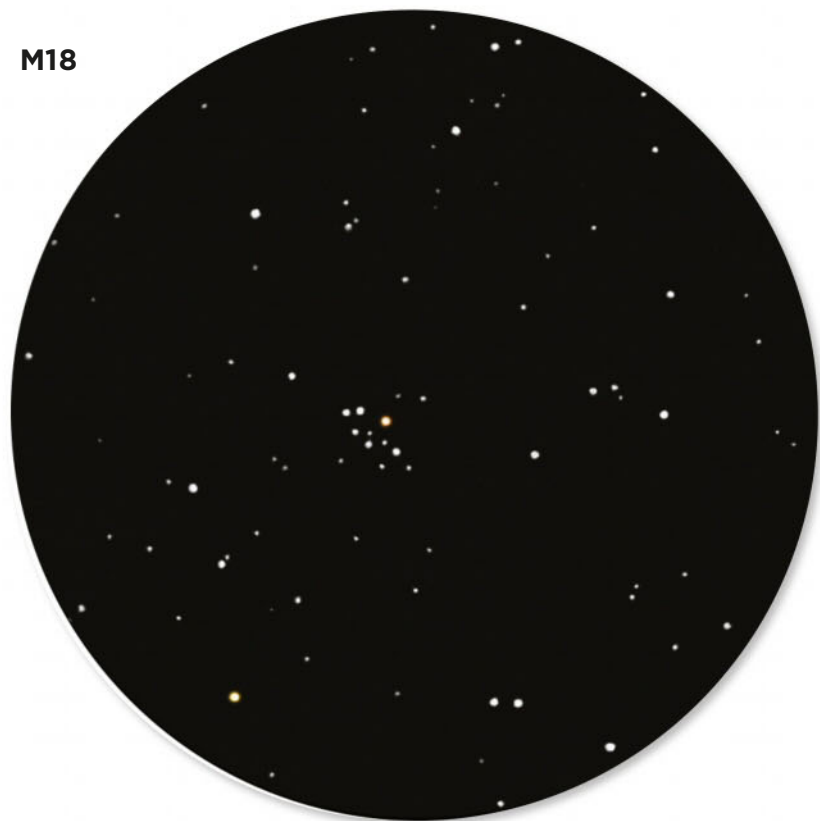
Through my 25-cm reflector at $115\times$, NGC 6567 presents a strikingly blue-green disk that I judge to be about $9''$ across.

A few other star groups from Charles Messier's famous 18th-century catalogue keep M24 company. Its nearest neighbour on the sky is the open cluster **Messier 18**, which hovers north of the star cloud's northeastern end. My 130-mm refractor at $48\times$ shows 15 moderately bright to faint stars, most arranged in a cute shape resembling a slightly mangled hairpin. At $91\times$ I count 24 stars loosely scattered across approximately $7\frac{1}{2}'$.

Two richer star clusters bracket M24. To the west we find **Messier 23**, which blossoms into a populous collection of 9th- to 12th-magnitude stars when seen through a 130-mm scope at $37\times$. The cluster spans about



M18



0.5° and boasts about 90 stars strung in glittering chains meandering through the group. Pushing the scope east from M24 brings me to **Messier 25**, a lovely cluster of 70 mixed bright and faint stars prettily displayed in sprays and gently curving lines. The four brightest stars shine gold, and there's an adorable little 'D' of seven faint stars at the group's heart. The

nice double star 3' south of the 'D' is **Burnham 966 CD** (β966 or BU 966), with a yellow primary whose companion rests 11" to its south. Altogether, the stars form a vaguely rectangular gathering that's about 40' long, tipped a bit east of north.

The Small Sagittarius Star Cloud plumbs our galaxy to considerable depth. Its stars spread from about

10,000 to 15,000 light-years away from us. This would include stars from the Scutum-Centaurus Arm, the major spiral arm between us and the galactic centre. M24 may also include stars within a minor spiral arm farther inward, the Norma Arm. Thus, M24 is not a true physical object, but merely a pile-up of stars along our line of sight.

At a distance of 12,000 light-years, NGC 6603 is actually within the bounds of the Star Cloud. It's difficult to tell where NGC 6567 fits into the scene. As is often the case with planetary nebula, even recent distance estimates are widely varied — in this case from 5,500 to 12,000 light-years. The other objects are in the foreground, and we simply see them projected against M24. Collinder 469 is about 4,800 light-years distant, while the dark nebulae are roughly 700 light-years away from us.

Most Messier objects are also listed in the 1888 *New General Catalogue of Nebulae and Clusters of Stars* (NGC), but neither M24 nor M25 is among them. They were added to the 1908 supplement to the NGC, known as the *Second Index Catalogue of Nebulae and Clusters of Stars* (IC). In the catalogue, IC 4715 (M24) is described as a most extremely large cloud of stars and nebulae and IC 4725 (M25) as a cluster, pretty compressed. We can just call them beautiful. ♦

Sue French welcomes your comments at scfrench@nycap.rr.com.

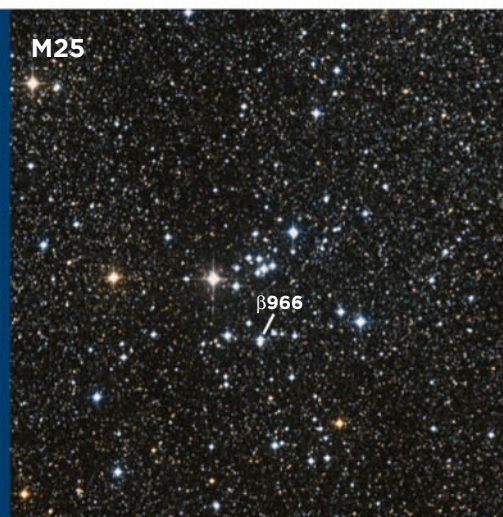
Deep sky targets in the Small Sagittarius Star Cloud

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Messier 24	Star cloud	2.5	2° × 1°	18h 16.8m	-18° 33'
NGC 6567	Planetary nebula	11.0	12"	18h 13.8m	-19° 05'
Messier 18	Open cluster	6.9	7.2'	18h 20.0m	-17° 06'
Messier 23	Open cluster	5.5	29'	17h 57.1m	-18° 59'
Messier 25	Open cluster	4.6	32'	18h 31.8m	-19° 07'

Angular sizes and separations are from recent catalogues. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

Right: The double star Burnham 966 CD (β966) lies 3' south of the D-shaped figure resting at the heart of open star cluster M25.

M25



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Saturn's polar polygon puzzle

Why is the ringed planet crowned by a hexagonal cloud pattern?

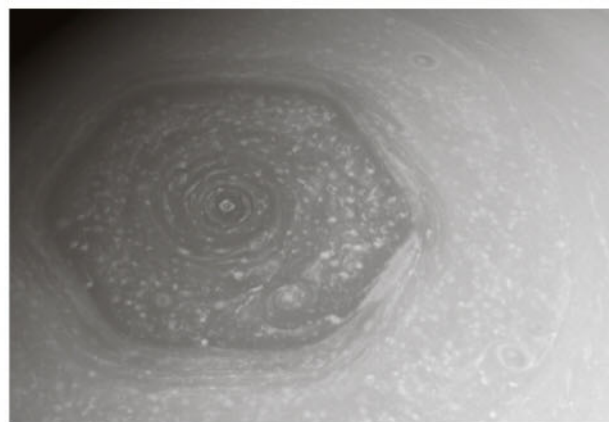
Saturn's rotational axis is tilted by almost 27° to the plane of its orbit, giving the ringed planet a full array of seasons. While seasons on Earth last only three Earth months, Saturn's endure for more than seven Earth years, owing to its 29.5-Earth-year-long orbital period.

The northern summer solstice on Saturn will occur in May 2017, when the planet's north pole and the northern face of its rings will be tipped toward the Sun — and toward Earth — to their maximum extent. While the increasingly apparent opening of the rings is undoubtedly the principal attraction, this favourable viewing geometry also affords an opportunity to observe colourful features at high northern latitudes on the planet's globe.

Saturn displays alternating dusky belts and bright zones that resemble

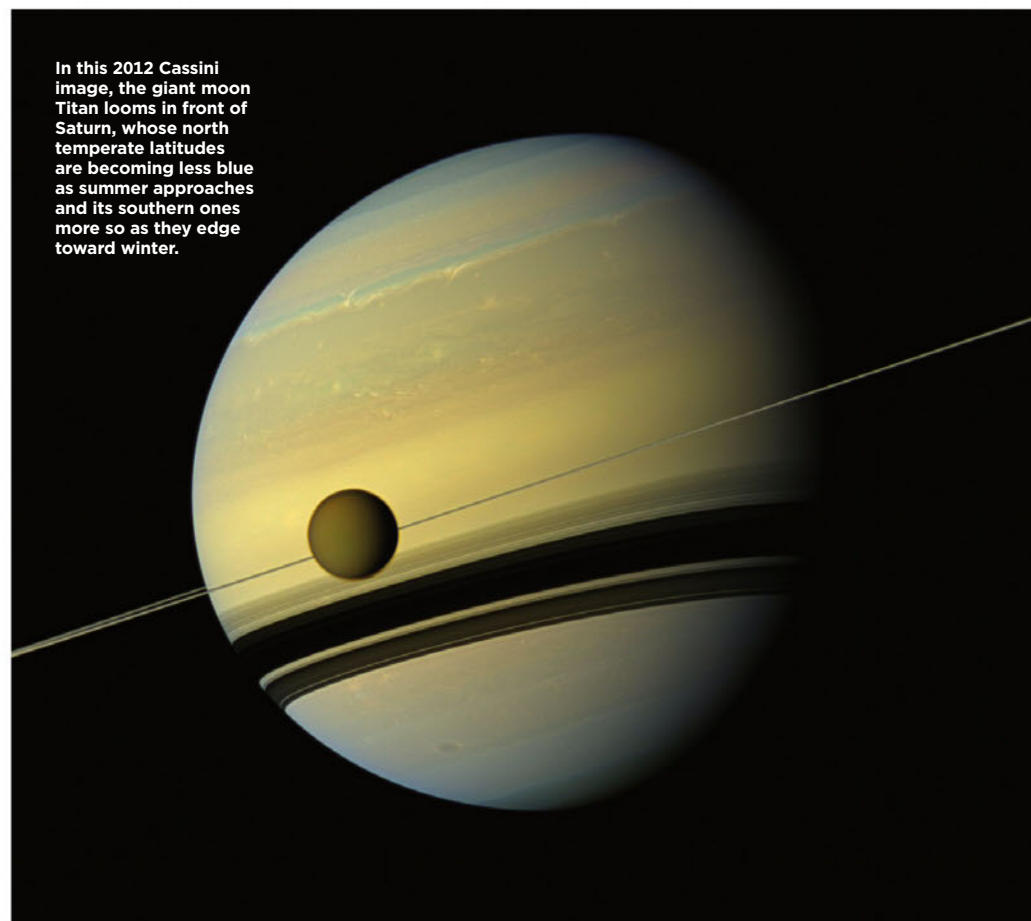
those of Jupiter but are comparatively muted in contrast and bland in appearance. In many respects, Saturn's atmosphere is similar in structure and composition to Jupiter's, with a deck of water clouds at the bottom, ammonium hydrosulfide (NH_4SH) clouds in the middle, and a deck of frozen ammonia (NH_3) clouds at the top — the one we see — discoloured by traces of nitrogen, sulfur and phosphorous compounds. The upper troposphere, which lies above this layered sandwich, consists of colourless hydrogen and helium with a trace of methane (CH_4) and a murky haze of photochemical smog.

Two factors account for the dramatic difference in the appearance of the two gas giant planets. Clouds form deeper down at the cooler temperatures that prevail at Saturn's greater distance from



Although seen distinctly at visual wavelengths, Saturn's enigmatic north-polar hexagon was even more striking when recorded in near-infrared light by Cassini in 2013. This feature, first discovered in Voyager images, is twice Earth's diameter in size. The day-night terminator is at upper left.

NASA / JPL / SPACE SCIENCE INSTITUTE (2)



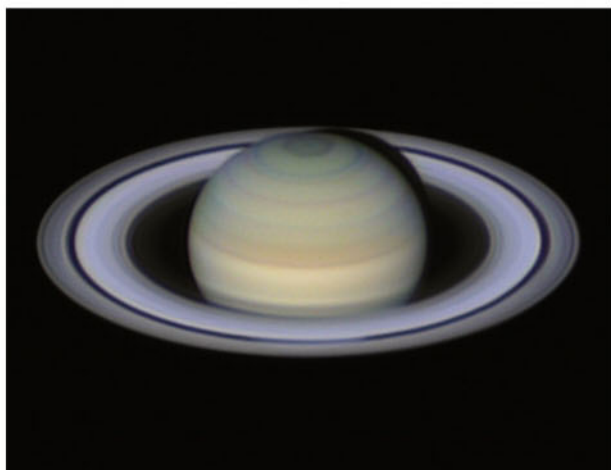
In this 2012 Cassini image, the giant moon Titan looms in front of Saturn, whose north temperate latitudes are becoming less blue as summer approaches and its southern ones more so as they edge toward winter.

the Sun. This thermal effect is greatly reinforced by the planet's weaker gravity. (Although only slightly smaller in diameter than Jupiter, Saturn is only 30% as massive.) Jupiter's atmosphere is pulled much more powerfully toward the centre of the planet, so the pressure gradient in the Jovian atmosphere is almost three times steeper.

Viewing Saturn's cloud deck through the planet's hazy, distended upper troposphere washes out details and subdues the saturation of colours. Saturn's dark belts appear pale greyish brown rather than the reddish sepia characteristic of Jupiter's belts, while the ringed planet's tropical and temperate zones feature a delicate palette of straw yellow, butterscotch and saffron hues.

Saturn's dusky polar regions, however, often display assorted cooler colours reminiscent of the frigid ice giants Uranus and Neptune. Ranging from olive green to teal, aquamarine and azure blue, they can be detected by a keen-eyed observer through a telescope of only 15- to 20-cm in aperture. Yellow (Wratten 12 or 15), orange (Wratten 21) and red (Wratten 23A or 25) filters enhance this distinction.

As long ago as 1806 William Herschel noted that Saturn's poles



Thanks to the favourable tilt of Saturn's north pole toward Earth, amateur astrophotographers are getting a good look at the planet's polar hexagon for the first time since its discovery in 1988. DAMIAN PEACH

appear to darken as they slowly tilt sunward. Decades of observations amassed by the British Astronomical Association's Saturn Section show a close correlation between solar altitude and the darkness of the polar regions, suggesting that Saturn's atmosphere responds quickly to the increasing input of sunlight.

The Sun's intensity at Saturn is only 1/90-th of that on Earth, and the ringed planet radiates about twice as much internal heat as it receives from the Sun. So warming temperatures are not responsible for intensifying the polar colours. Instead, the greenish and bluish hues are widely attributed to Rayleigh scattering by hydrocarbon aerosols produced by solar ultraviolet radiation and charged particles, augmented by the selective absorption of light from the red end of the spectrum by methane. But the chemistry of Saturn's polar hazes is surprisingly complex — for example, polarimetry data suggest that the haze particles are shaped like microscopic grape clusters — and in truth the exact cause for the distinct hues remains uncertain.

A curious aspect

Saturn's colourful northern polar region is the site of a persistent hexagonal-shaped cloud feature centred at latitude 76° north. Curiously, it has no counterpart at the planet's south pole. First noticed in 1988 on old Voyager spacecraft images, it was still present and seemingly unaltered when the Cassini spacecraft imaged Saturn's

north pole in 2006. The Voyager images revealed that clouds along the hexagon are propelled by fierce jet-stream winds that exceed 400 kilometres per hour.

Physicists at the University of Oxford recently recreated the appearance of this mysterious feature by placing a cylinder of water on a slowly spinning table to simulate Saturn's atmosphere spinning with the planet's rotation. Inside this vessel they placed a small ring that rotated more rapidly than the cylinder to mimic an atmospheric jet stream. The researchers used fluorescent green dye to make the currents visible. They soon noticed that the greater the difference in rotation rate, the less circular the turbulent boundary became. Stable vortices of similar size formed on the slower, outer side of the fluid interface, and these interacted with each other to space themselves out evenly around the perimeter. By varying the rate at which the inner ring spun, the investigators were able to generate a variety of polygons, but a hexagonal form was

the most common and stable. You can watch a video of the simulation at http://is.gd/saturn_hexagon.

Is that what's happening on Saturn? Perhaps, though Cassini has not observed any differential rotation between the hexagon's interior and exterior. Also, why is there no comparable feature surrounding the planet's south pole?

In any case, the north-polar hexagon is huge, spanning 25,000 kilometres (twice the diameter of Earth), and it subtends more than 3 arcseconds for earthbound observers — four times the apparent diameter of Titan, Saturn's largest satellite. Although well-equipped webcam imagers are routinely capturing stunning images of this feature, discerning its straight-sided outline poses a challenging test for purely visual observers. But don't let that dissuade you from trying. Saturn reached opposition in late May, so now is an excellent time to see the ringed planet at its best — hexagon or no. ♦



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Faulting the lunar crust

Subtle cracks and creases betray shifts in the lunar landscape.

The realisation in the late 1940s that the Moon's dark, circular maria exist within very large impact craters (called basins) was profoundly important. Excavated during titanic impacts, these big, deep holes threw their ejecta widely across the Moon, later became filled with mare lava flows, and eventually developed concentric fractures and mare ridges as

they subsided. Basins are thus the most important lunar landforms.

When observing the Moon, your eye is drawn to the major lava-filled basins such as Imbrium, Crisium, Humorum and Nectaris, but numerous smaller ones are often overlooked.

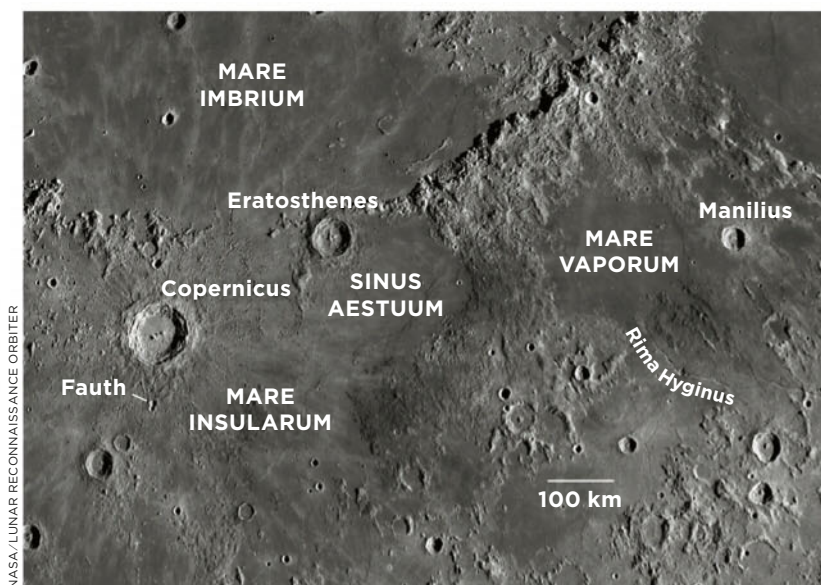
A powerful tool that has helped geophysicists recognise basins is the global gravity map created by

NASA's Gravity Recovery and Interior Laboratory (GRAIL) orbiters, twin craft that circled in tandem at low altitude before crashing onto the lunar surface in December 2012. New Zealand amateur Maurice Collins created the colour map at lower left that is a mash-up of GRAIL gravity data with a visualisation of Lunar Reconnaissance Orbiter digital topography. The area shown, about 1,000 kilometres wide, stretches from west of Copernicus to just east of Manilius.

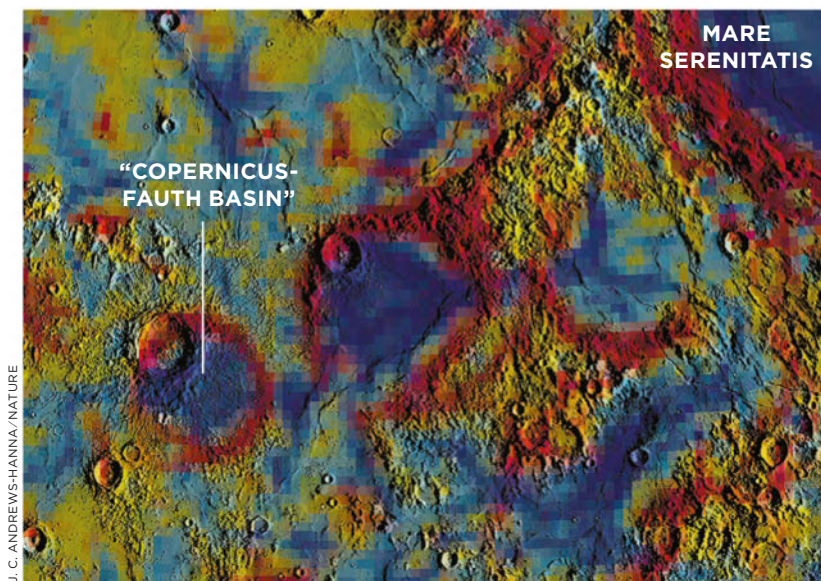
The map's colours represent the local gravity field gradients (from an analysis by Jeffrey C. Andrews-Hanna of the Colorado School of Mines), with blue indicating where the field is stronger, and red weaker, than average. These variations result from the amount of mass present near the lunar surface. A lower-mass signature can be caused by a big hole in the ground or by lower-density rocks such as those of the lunar highlands. Higher gravity readings require dense rocks such as lava flows or, more importantly, an upwelling of the lunar mantle beneath the surface.

Basins are usually surrounded by uplifted circular rims of pulverised, overturned rock that create gravity 'lows' (notice the red rim of Serenitatis at upper right). The interiors of many basins are pronounced gravity 'highs,' the famous mass concentrations or mascons discovered in the early days of lunar exploration.

The exceptional spatial resolution of the GRAIL data allows unprecedented delineation of gravity highs and lows, and Collins' mash-up clearly defines three smaller basins southeast of Mare Imbrium. Two of these can be seen by



NASA/LUNAR RECONNAISSANCE ORBITER



J. C. ANDREWS-HANNA/NATURE

Top: The lunar landscape between Copernicus and Manilius features several small maria. Two of these fill the basins Aestuum and Vaporum. **Bottom:** A third basin, now covered by Mare Insularum, only becomes evident in the gravity map of this region compiled by NASA's Gravity Recovery and Interior Laboratory (GRAIL) spacecraft. Red regions denote gravity fields that are lower than average and blue ones those higher than average.

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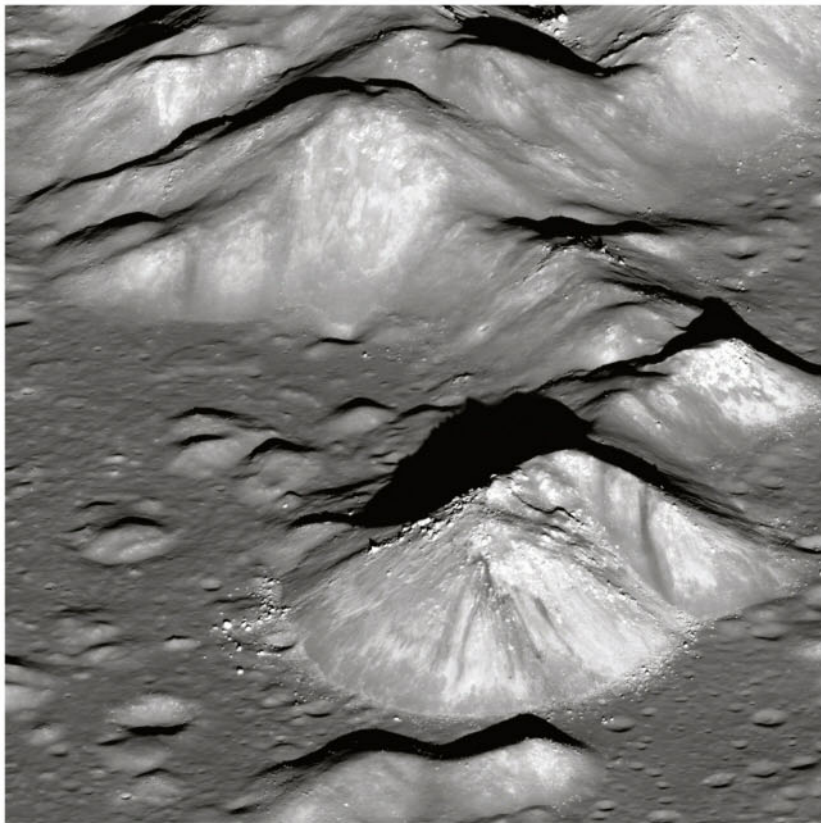
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The central peaks in Copernicus, as seen obliquely from the west by NASA's Lunar Reconnaissance Orbiter. They rise about 700 metres above a sharp boundary with now-solid lava that was liquefied by the impact's energy and flooded the floor of the crater in its final stages of formation. NASA/LUNAR RECONNAISSANCE ORBITER

eye in the topography, but the third is nearly invisible.

Mare Vaporum very likely fills a small impact basin even though it isn't ringed with mountains. Instead, notice the modest gravity high caused by dense lava filling a depression. GRAIL data clearly show a curved red rim on the southern side of the mare. The diameter

of the Vaporum basin, as defined by the partial red ring, is about 250 km.

At the telescope you can see that the end of the rille **Rima Hyginus** abruptly stops when it reaches the southeast edge of Mare Vaporum, showing that those lavas are younger than the rille.

A more pronounced red gravity ring defines the basin of **Sinus Aestuum**,

which does not retain any remnant of its topographic rim except for the isolated mountain southwest of Eratosthenes. We used to think this little elongated mountain was an isolated plop of Imbrium ejecta, but the gravity data suggest that in reality it's part of the small basin's rim. Based on the red gravity ring, the basin is about 275 km wide.

The Aestuum mascon is more pronounced than Vaporum's, perhaps indicating a thicker lava filling. The ridges that form an inner basin ring at Aestuum were produced by faulting in the mare when the underlying basin subsided.

A red ring and blue mascon 'bull's-eye' defines a third small basin on which **Copernicus** later appeared. This small, 200-km-wide basin displays no convincing evidence of a topographic rim and, unlike Vaporum and Aestuum, wasn't identified previously. Some lunar geologists suspected it was the eastern half of a larger, rather speculative basin called **Insularum**. However, thanks to the GRAIL data, we now know that no basin underlies **Mare Insularum**. So, to avoid confusion, I informally call this newly recognised feature 'Copernicus-Fauth basin', after the only two named craters within it.

The fact that Copernicus formed directly above the basin's now-absent rim might explain a peculiar compositional aspect of the crater's central peaks. These contain the mineral olivine, thought to be common in the lunar mantle. The rim of the Copernicus-Fauth basin might include olivine excavated from great depth and later brought to the surface as the Copernicus peaks.

Volcanism, which commonly occurred inside large basins, also marks all three of these smaller ones. For example, a small, steep-sided volcanic dome was recently recognised along the north shore of Mare Vaporum. The Moon's most extensive deposits of pyroclastic (ash) material occur along the eastern and southern shores of Aestuum, and a similar deposit lies along the southeast rim of my Copernicus-Fauth basin.

All of these volcanic features can be observed with a telescope, but it's a bigger challenge to find evidence for the rims of these three small basins. ♦

Charles Wood (lpod.wikispaces.com) is co-author of the new book 21st Century Atlas of the Moon.

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2nd October An evening of banter and debate with science broadcaster and journalist, Robyn Williams, internationally acclaimed astronomer Prof Amanda Bauer, Prof Naomi McClure-Griffiths, Prof Lisa Harvey-Smith and Prof Vicki Meadows.

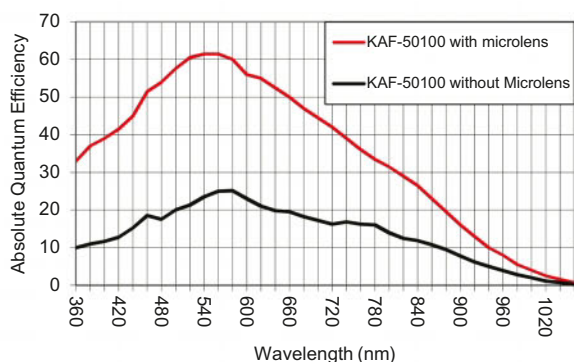
Milroy StarBQ Party - 3rd October
Experience the best Southern Sky by night. Viewing through the 40" telescope and other large Dobsonian telescopes. Cam Wylie will give a talk about the night sky as you enjoy the nights Star-B-Que.

Bok Lecture - 4th October
Prof. Vicki Meadows is the Principal Investigator for the NASA Astrobiology Institute's Virtual Planetary Laboratory Lead Team and a Professor with the University of Washington. Prof Meadows' primary research interests are in determining how to recognise whether a distant extrasolar planet is able to harbor life.

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interstellarum Deep Sky Atlas

Ronald Stoyan and Stephan Schurig
Oculum-Verlag GmbH and Cambridge University Press, 2015
Desk Edition, 264 pages, ISBN 9781107503380
Field Edition, 264 pages, ISBN 9781107503397

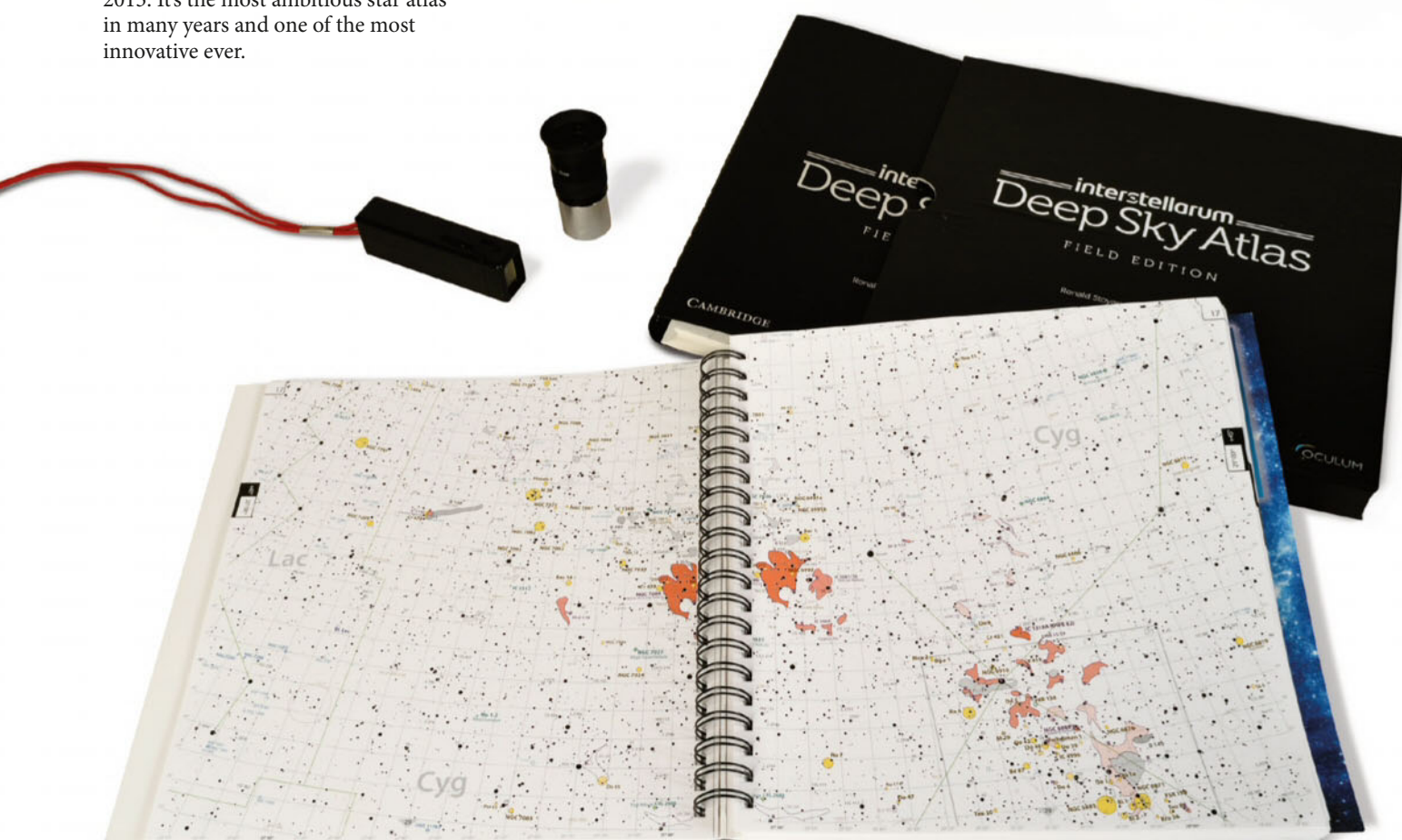
Is there a future for paper star charts in an era of computers and hand-held electronic devices? Cambridge University Press and German publisher Oculum-Verlag seem to think so. They've collaborated to produce an English-language version of the *interstellarum Deep Sky Atlas*, which has been available in German since late 2013. It's the most ambitious star atlas in many years and one of the most innovative ever.

Viewed in daylight, the atlas is gorgeous. It comes in two different editions with identical contents. The Desk Edition is printed on high-quality paper, while the Field Edition is printed on synthetic paper that's waterproof, light and tough. Facing pages form a single spread when the atlas is laid open on a table, and the

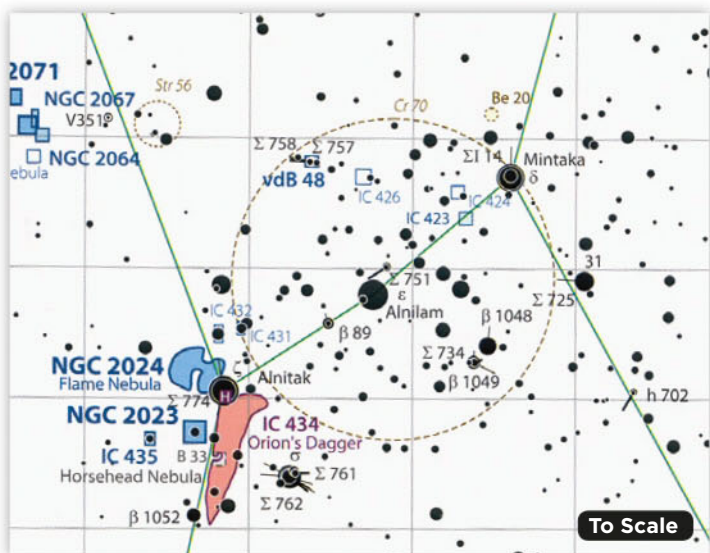
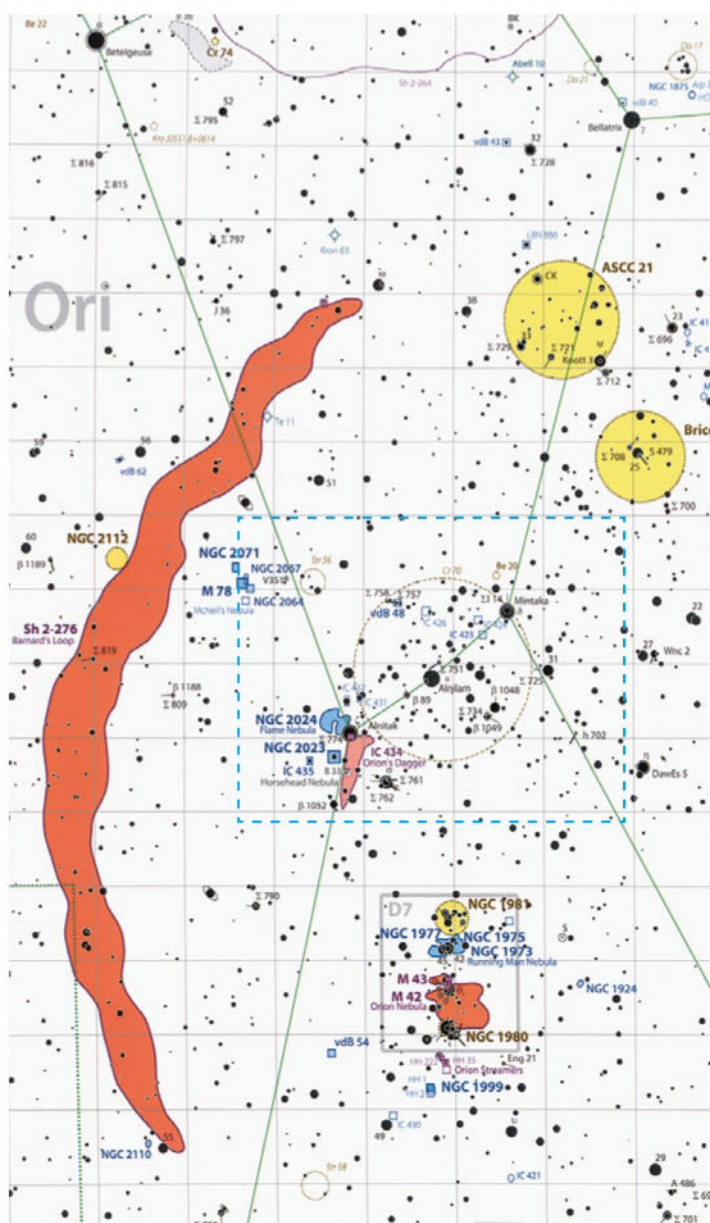
wire binding makes it easy to fold the atlas back into single-page format. I found the volume easy to hold next to the eyepiece of a telescope or finderscope by resting it in the crook of my elbow. That's much more convenient than running back and forth between the telescope and the observing table when working out a complex star-hop.

With thicker, whiter paper, the Desk

At 28.7 × 28.5 cm and 1.3 kg, the Field Edition is easy to hold next to the eyepiece of a telescope.



S&T: SEAN WALKER



As the chart of Orion shows, the more vibrant the colour, the smaller the instrument needed to spot the target. Galaxies are shown in blue, reflection nebulae in a paler blue, planetary nebulae in green and emission nebulae in salmon with a dark outline. Labels vary in size to reflect an object's visibility.

Edition is indeed slightly easier to read at a desk, while the Field Edition's lighter weight makes it easier to hold next to the eyepiece. The Field Edition will presumably hold up longer against dew, but the Desk Edition is also highly dew resistant. In fact, both editions work very well both day and night.

The colour scheme is carefully chosen; it provides extra legibility during the day but also works well by red light. Unlike most recent atlases, this one depicts galaxies as blue, making them quite prominent by red light. Reflection nebulae are shown in paler blue and emission nebulae in a salmon colour with a dark outline — a useful distinction not made in most star charts. For more of the atlas's many innovative features, see deepskyatlas.com.

The atlas aims to show all deep sky objects visible through a 30-cm scope under dark skies, as well as some fainter objects of special interest. That adds up to 15,000 deep sky objects, which are plotted on a field of 200,000 stars down to magnitude 9.5. In addition to the 114 basic charts, there are 29 detailed charts for crowded fields. Deep sky objects are divided into four classes depending on the aperture needed to see them: 10-cm, 20-cm, 30-cm or more. The objects' labels are scaled according to their visibility class, just as major cities get larger labels than do small towns on a conventional road map.

To see how this all works out in practice, I took the atlas out for two long nights of observing with my 31-cm Dobsonian. For comparison, I also brought my 7-inch tablet running a planetarium app.

The planetarium app is excellent in many ways. It's tremendously flexible and configurable, and it can display far more stars and deep sky objects than any paper atlas ever produced. However, paper charts have compensating virtues. They're easier to read without losing dark adaptation and considerably easier to manipulate with cold fingers. Above all, paper can show far more information at a single glance.

The *interstellarum Deep Sky Atlas* charts are printed right to the edge of the page, with zero wasted space. (Page numbers and coordinate grid labels are overlaid on the corners and edges, in the space that's overlapped between adjacent maps.) Each two-page spread has 10 times the area of a chart on my 7-inch tablet. That allows a spread to cover more than 500 square degrees of sky, or about the size of an average constellation. Constellation lines are drawn in, which made it easy for me to get my initial fix on the sky. The stars plotted in the atlas are an excellent match to those visible through my 8×50 finderscope, so I could then star-hop to the correct low-power telescopic

eyepiece field in just a minute or two. I could see all relevant levels of detail at a glance in the atlas. That would require several pan-and-zoom operations with my planetarium app; my tablet's tiny screen can show either the big picture or the small, but not both together.

It was only when I arrived at my destination that I started to appreciate the atlas properly. My usual observing style is to seek out a specific object and then poke around and see what else is worth looking at in the vicinity. That's hard to do with most highly detailed atlases, which show thickets of nearly identical symbols in any crowded galaxy cluster or Milky Way field. The different-sized labels in the *interstellarum* atlas bring a crowded field to life, giving a sense of the character and diversity of the individual objects. I could then start with the most prominent ones and work as far down the visibility classes as I liked.

In addition, the atlas marks double and multiple stars with ticks whose length indicates the component stars' separation, and each of the 2,950 double stars is labelled with its name. I'm a huge double star fan, so this

pleases me greatly.

Of course, no atlas is perfect, and due to its huge ambition and originality, the *interstellarum* atlas has more flaws than most. The biggest labels are delightfully legible, but the smallest are pretty hard to read. That's arguably appropriate when you're labelling a very faint object. But I rely heavily on right ascension, declination and Greek Bayer letters for stars, and those are also in minuscule type. And the atlas never uses leader lines to connect symbols to their labels. That sometimes makes it hard to puzzle out the correspondence in a crowded field.

Although the atlas claims to be complete for 30-cm scopes, it doesn't plot all the objects I've spotted with my 31-cm scope. For instance, I found six galaxies inside Messier 44 with my 31-cm. The atlas only plots two — and they're not the ones that I found easiest to see. Nonetheless, it certainly shows almost all objects of interest to me or most other backyard astronomers.

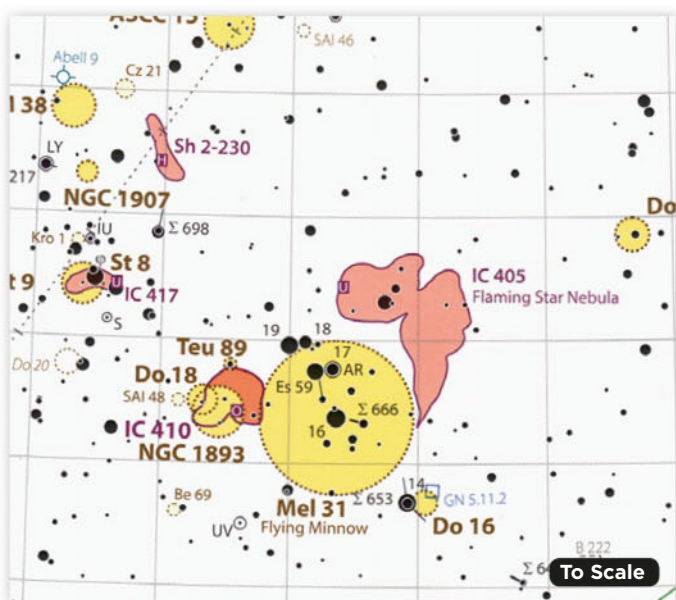
The atlas is very strong on open clusters but possibly goes a little too far in this direction, showing some large, obscure open cluster candidates with no little or no visual appeal. I would

also prefer fewer asterisms and fewer nicknames for deep sky objects.

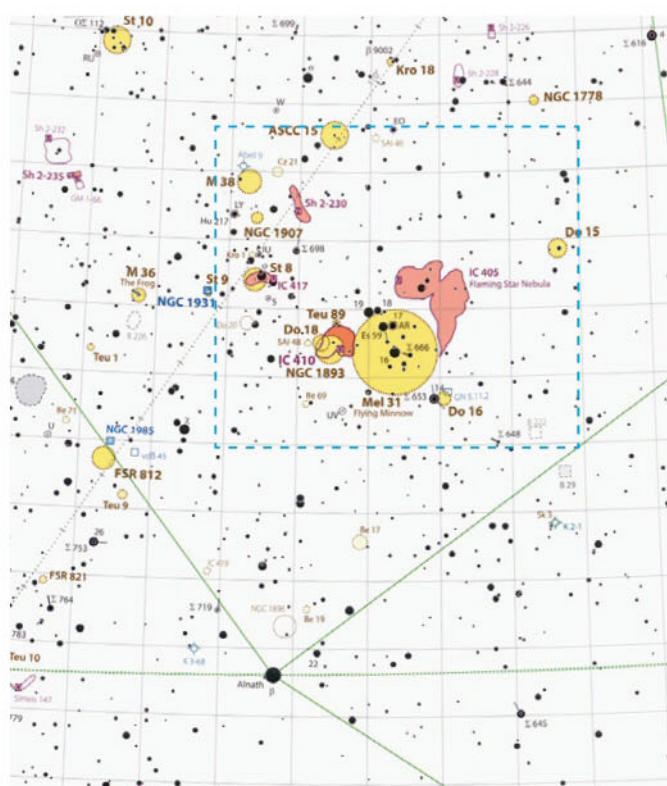
But to some extent this is quibbling. All star charts require choices and compromises. The *interstellarum Deep Sky Atlas* comes very close to maximising the information that can be shown in a convenient, hand-holdable atlas without compromising clarity. I find that it adds more to my observing sessions than any other printed atlas I've used.

The atlas' biggest limitation is its scale and star depth: they aren't really adequate to pin down the locations of its faintest objects. But that's where my planetarium app comes into its own. If I can't spot my target immediately once I get down to the medium-power eyepiece level, I bring out my tablet, with its inexhaustible supply of faint stars, to help me finish the job. I don't see the atlas and app as competitors; instead I find that they complement each other perfectly — the atlas for the big picture and the app for the nitty-gritty details. ♦

Tony Flanders produced almost 1,000 star charts while he was an associate editor at Sky & Telescope.



The limiting magnitude of the atlas is 9.5. As is shown here with $\Sigma 666$ in Auriga, double stars are marked with ticks, the length of which indicates component separation. Each of the 2,950 double stars included is labelled with its name. Also shown are 1,168 variable stars with a maximum magnitude brighter than 9.0.



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A minimalist telescope

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Most home-built scopes are variations on existing designs, but through little tweaks and additions become something unique. Michael Wolfson's 37.5-cm Newtonian reflector is a fine example.

"After acquiring many telescopes while searching for the sweet spot between portability and performance, I concluded that an ultra-light Dobsonian was the way to go," Michael says. He wanted the greatest aperture with the least weight, in a scope that he could use without a ladder or step stool.

Albert Highé's book, *Engineering, Design and Construction of Portable Newtonian Telescopes*, which details

building highly portable large-aperture scopes, was one source of inspiration and ideas. Michael had also seen a single-strut Newtonian at a star party, which prompted him to build several smaller versions to gain experience. So when he acquired a 37.5-cm f/4.6 quartz primary mirror, the broad outlines of his new scope were set.

One feature that Michael put his own spin on was the scope's bearings. "Instead of counting on Teflon and Formica to provide just the right balance of stiction and friction," he explains, "I decided to start with bearings that move as freely as possible, and then increase the friction in a controlled manner."

His solution uses a 33-cm-diameter lazy Susan bearing in azimuth, and aluminium semi-circle plates riding on cam-follower bearings for the altitude. This arrangement is well suited to a motor-drive system Michael plans to add in the future. But for controllable manual slewing, some additional friction is required. To achieve this, Michael resorted to some old-school Dobsonian technology. On the azimuth axis, he affixed a 38-cm-diameter circle of laminate between the ground board and the lazy Susan bearing, with only the outer couple of centimetres of the laminate exposed. With the turn of a knob located inside the rocker box, a thick pad of Teflon gradually presses against the outer edge of the laminate disk, increasing friction. For the altitude motion, the aluminium bearing on the focuser



A Teflon pad bears against Formica to regulate friction in the scope's azimuth axis. A knob controls the pressure.

MICHAEL WOLFSON

side of the scope moves between two pieces of Teflon: one attached directly to the interior of the rocker box, the other screwed to an adjustable, spring-loaded aluminum plate. Tightening a knob forces this second Teflon piece against the altitude bearing, sandwiching it between the two pads — similar to an automobile disk brake.

His scavenging skills were also put to good use when it came to the primary mirror tube assembly. For this part, Michael repurposed a 40-cm-diameter, 6-mm-thick drum shell, salvaged from a local music store. He sanded off the drum's original finish, then applied several layers of clear Varathane to the outside and a coat of flat-black paint to the interior.

Another nifty refinement is the ability to move the focuser and secondary mirror assembly up and down the strut pole. "If I want to use my bino viewer," he explains, "all I have to do is loosen the U-bolt clamps, slide the assembly closer to the primary mirror, then recollimate and rebalance."

Michael's lightweight and versatile scope is tailored to his observing needs. "There are many lovely trees around, so depending on which part of the sky I want to observe, it's helpful to be able to easily relocate the scope — exactly why I wanted one that's lightweight and quick to set up," he says. ♦

Contributing editor Gary Seronik is an experienced telescope maker and observer. You can see some of his lightweight scopes on his website at garyseronik.com.

Right: Michael Wolfson's 37.5-cm f/4.6 Newtonian reflector combines excellent portability and performance. Bottom: Friction in the altitude axis is controlled by turning a hand knob, which pulls a pad of Teflon against the inside surface of one of the aluminium side bearings.

MICHAEL WOLFSON (*)



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Today's one-shot colour cameras can take world-class astrophotos. Here's an easy way to make your images shine.

In the realm of deep-sky imaging, single-shot colour cameras have long played second fiddle to their monochrome cousins paired with colour filters. While monochrome cameras are generally more sensitive and produce the best results, the difference isn't so obvious anymore. Today's one-shot colour cameras, combined with the latest processing software, can produce stunning astrophotos that rival the best, typically with a lot less money and time spent.

What is one-shot colour?

One-shot colour (OSC) cameras are actually monochrome sensors with one important addition. Unlike a monochrome detector, OSC sensors are covered with a microscopic grid

of filters known as a Bayer matrix, named for its inventor, the late Dr Bryce Bayer. This grid places a red, green or blue filter over each individual pixel. When an exposure is made, the colour information is immediately available, unlike with monochrome cameras, in which you must take individual exposures through separate filters and then combine them to reveal the colour. Most digital SLRs (DSLRs) are built around OSC CMOS sensors, and some astronomical cameras are available with OSC CCD detectors. While an OSC device eliminates the

need to shoot through individual colour filters, making it easier than ever to take colour astrophotos, it does have some limitations.

The Bayer matrix's ability to collect colour in a single exposure prevents the collection of unfiltered luminance. As each pixel always 'looks' through an attenuating filter, the detector's quantum efficiency (or sensitivity to light) is limited by those same filters. Because the Bayer filter divides the sensor into three images (50% green, 25% red and 25% blue), the information is inherently of lower resolution than images captured with

ALL IN ONE The best colour deep-sky astrophotography used to be the exclusive realm of monochrome cameras equipped with individual filters, leaving many amateurs to assume that images like this photo (above) of the Leo Trio of galaxies are beyond their reach. Author Warren Keller shows you how this really isn't the case anymore. All images are courtesy of the author.

a monochrome camera. The OSC colour channels are interpolated to fill in the gaps between the pixels, though the latest interpolation routines make this difference nearly imperceptible. Finally, while narrowband filters are available for OSC cameras, the loss of light sensitivity when combined with the Bayer filter makes imaging through them a challenge.

Despite these limitations, OSC cameras can be fantastic performers, particularly when used under dark skies with fast focal-ratio optics, and they are the perfect complement to fast astrographs such as Celestron's Rowe-Ackermann Schmidt Astrograph.

Taking OSC astrophotos

Capturing images with an OSC camera is certainly simpler than with monochrome detectors, but most of the technique is the same. As with all deep sky imaging, exposures should be long enough to produce adequate signal. Depending on your focal ratio, 16 or more 5- to 10-minute exposures should be adequate to produce a smooth result.

Image calibration is nearly as important with OSC images as it is with monochrome cameras. Most recent models of DSLR cameras and many astronomical OSC CCD cameras are based around extremely low-noise sensors, making dark frame subtraction (and bias calibration) often unnecessary. However, flat-field calibration frames may still be required. These are exposures of an evenly illuminated surface that record vignetting or out-of-focus dust in your optical system. These images are then applied to your light exposures to remove their effects from your images.

Debayering

Before calibrating and combining your images, your first task is to determine your particular CCD sensor's filter pattern. I enjoy using Astroart (msb-astroart.com) software when processing my OSC images, because it includes many tools designed specifically for OSC data. Opening an unprocessed OSC FITS or RAW file in Astroart reveals a greyscale image with a grid-like appearance. As mentioned earlier,

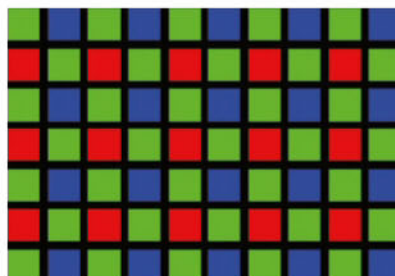
the detector in your camera records a monochrome image with a pattern of tiny filters over the sensor, so what you see here is the difference in light sensitivity of your sensor to red, green and blue light. This now requires converting into colour images through a process called debayering, which extracts the colour information from the grid.

With your first image open in Astroart, select Colour > CCD Colour synthesis. Astroart requires you to establish the order of the Bayer filters in their sensors by adjusting the 'Synthesis, XY Offset?' numbers and clicking OK. In this new window, a greyscale and colour grid representing the filter matrix is displayed. Matching the brightness value of the greyscale grid to the colour grid should help to guide you to the proper setting. Try the default settings first by clicking the OK button, but if the result appears monotone green or blue, these default offsets are incorrect. Try different combinations by changing

the top offset from 0 to 1, and continue until a natural colour image is produced. Once the conversion parameters are established, close the image without saving any changes; the software will store these settings until you change them to accommodate a different camera. They will be applied momentarily.

Calibration and stacking

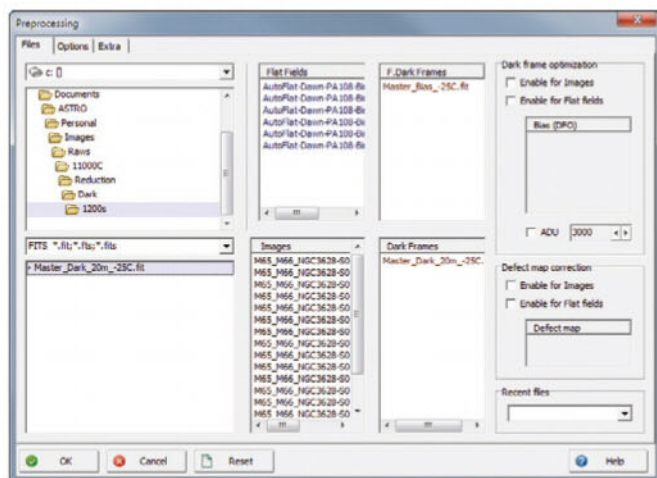
Now that you've established your debayer settings, open the Preprocessing tool (Tools > Preprocessing). In this window you'll select, combine and apply your calibration frames to your light images, as well as execute a number of other actions that will result in a final calibrated stack of all your images. Beginning with the Files tab, navigate to the image folder where your light exposures reside and drag them to the Images section at the right. Do the same for any corresponding flats, darks and bias images and place them in their respective boxes.



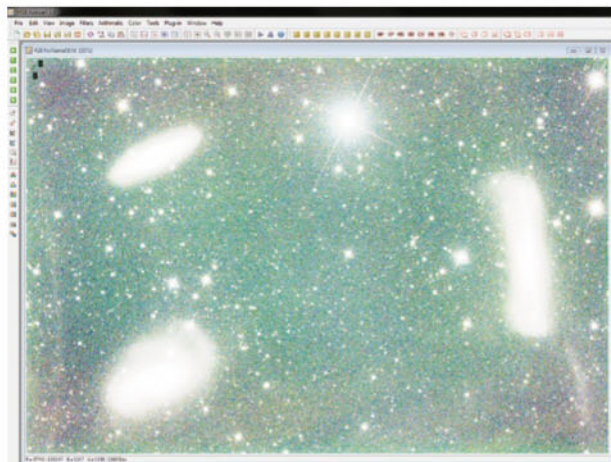
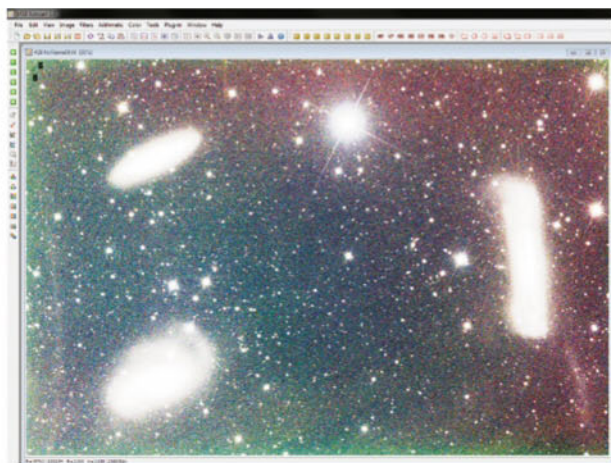
Left: BAYER MATRIX Colour cameras have monochrome detectors with a microscopic grid — known as a Bayer matrix — of red, green or blue filters placed over each pixel. This information is then re-interpreted as the colour image.

Below: RAW GRID Unprocessed RAW or FIT astrophotos appear as black-and-white images with a grid-like appearance.

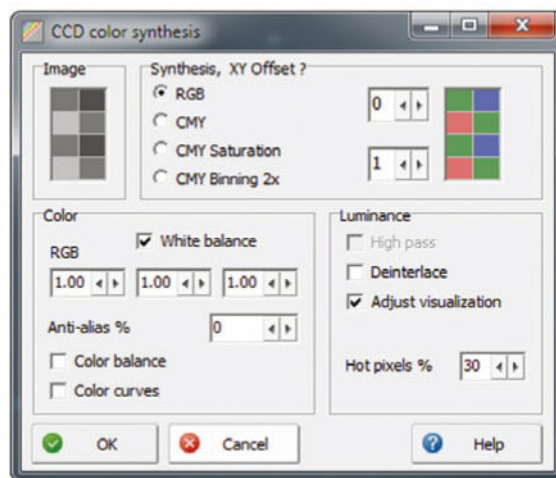




PREPROCESSING Astroart combines all of the routine calibration, image alignment and stacking actions into one easy-to-use tool called Preprocessing (above left). Here you can add all of your light images and calibration frames and perform everything necessary to produce a smooth image ready for enhancement.



GRADIENT REMOVAL Once you've calibrated and stacked your images, address any gradients. Pressing F5 on your keyboard will equalise the image and help reveal any gradients in your image. Select **Filters > Remove gradient** and select the tool that best describes the gradient or vignetting present in the image. If you're unsure which filter is the best fit for your data, Adaptive (subtract) is the most powerful and versatile choice.



Converting your RAW or FITS image in Astroart requires you to experiment with the order of the filters. Change the Synthesis, XY Offset ? from 0 to 1 and click OK to find the proper order of your camera's filter array.

Next, click on the Options tab at the top left of the Preprocessing tool to select the actions that will be applied to all your images. Begin here with the Result image section, and choose the type of image stacking algorithm you prefer to use. Sigma (Average) is my preferred combination method. This produces a strong signal-to-noise ratio, while rejecting outlier pixel values such as satellite trails, hot pixels, and other random signal that doesn't repeat in every exposure.

Adjust any other settings you want to apply to your images here. For example, select Auto Alignment to open another dialogue box that offers a few alignment options depending on your subject and guiding. You can experiment to determine which alignment method best suits your images.

Clicking on CCD colour synthesis reopens that dialogue we explored earlier. Confirm that your offset settings are correct, though you may want to increase the Hot pixels threshold, particularly if you forgo dark calibration.

If you're combining multiple calibration frames, you'll need to choose the method of combination for each at the bottom of the tool window. Finally, the Extra tab offers additional options which, when enabled, may be applied before or after calibration. This section is particularly useful for removing bad columns and rows from your images before combining the result.

Experiment with some of the other tools found in the program until you're satisfied with the results.

Now that you have all your preprocessing actions prepared, click OK, and Astroart will methodically reduce all your data into a final, smooth result ready for additional processing. Be sure to save this image before applying any additional processing; this is your 'master' stack.

Your stacked image should look pretty good. At this stage you should address any colour gradients. Press F5 on your keyboard to activate the 'Equalise' function. This displays the image with a strong non-linear stretch, which helps to reveal any background illumination issues (clicking F8 returns your image to a linear display). Be sure to crop away any black border in the image that is leftover from aligning the individual frames. If there are gradients, simply apply **Filters > Remove gradient > Adaptive (subtract)**. This should produce a much more even background. At this point you can experiment with the program's various



END RESULT Final tweaks, including sharpening, noise reduction and colour saturation adjustments, can all be performed in Astroart 5 to produce a final result indistinguishable from images assembled using the tri-colour method. This detailed image was captured through a 25-cm Ritchey-Chrétien telescope equipped with an Atik 11000C one-shot colour CCD camera.

deconvolution filters (Filters > Deconvolution) to tighten up any small-scale details.

Once you have sharpened and addressed any gradients in your image, it's time to 'stretch' the data into an artful photograph. Astroart's DDP (Digital Development Process) is an easy and effective way to perform non-linear stretches in your image as well as enhance subtle contrasts. You can apply the default setting or lower the Threshold and High pass: Sigma levels to compress the dynamic range to better display the entire brightness levels in your image. Also adjust the High pass: Strength to between 0 and 10 to enhance details in your nebulae and galaxy images. Clicking OK yields a beautiful, non-linearly stretched image with enhanced midtones and compressed highlights.

While the image remains a bit dark, you can fix this with the Filters > Histogram stretch. Activating this

filter displays a histogram with a few options; click the CURVES button, which allows you to manipulate the high, low and mid-points of the histogram, if needed.

Finishing touches

With our image now nonlinear, you can increase the colour saturation (Colour > Saturation). This tool allows you to limit the saturation increase to only the brighter areas and avoid increasing colour noise in the sky background.

At this stage, you may want to suppress any graininess in the sky background. Use the Low Pass filter (Filters > Low pass) to address this issue. Be sure to check the 'Enabled' box to activate the Adaptive function. This helps you limit the filter's effects to the background and low-signal areas of your image.

Now your photograph is just about complete. You can further enhance it using Astroart's Unsharp Mask filter

(Filters > Unsharp mask) or by increasing contrast before saving the final results. Experiment with some of the other tools found in the program until you're satisfied with the results — there are no hard rules to adhere to at this point. After all, you are your biggest critic!

Today's one-shot colour cameras, combined with the latest image-processing software, are capable of producing stunning deep-sky images that are virtually indistinguishable from those produced with a more complex setup. So if the cost and patience required for tri-colour imaging is more than you are currently willing to invest, a one-shot colour CCD or DSLR camera may be your best shot at producing beautiful astrophotos. ♦

Warren Keller produces a series of image-processing tutorials to help you get the most out of your images — go to ip4ap.com.

Organised observing

Deep-Sky Planner 6

Software designed
to help you get the
most out of your time
at the eyepiece

Deep-Sky Planner 6
Available on CD-ROM or as a download
knightware.biz

I'll admit I'm not the most organised person in the world. It's all too common for me to forget to pick up the bread at the shops or take a wrong turn on the highway. But on the observing field it's different — I always know where I'm going and what I want to see through my telescope. That's because I have a plan in the form of an observing list.

Making observing lists used to be a pain, particularly when paging

through dusty books and atlases to choose targets of interest. Fortunately, there's now software that takes the pain away. The main purpose of a planner is to help you easily compose observing lists and record your observations. Of the numerous observing planners on the market, Knightware's *Deep-Sky Planner 6* (DSP 6) is the most mature, having been continuously updated for more than 20 years.

DSP 6 is available on CD-ROM or as

WHAT WE LIKE:

- Large databases
- Works with popular planetarium software

WHAT WE DON'T LIKE:

- 'Slew To' button hard to find
- Does not automatically open last observing plan

a digital download from the company's website. The file is only 59 megabytes, so it doesn't take long even with sluggish download speeds.

Having used previous versions of the software, I was eager to try *DSP 6* because author Phyllis Lang has added some useful new features and improved on the existing ones. Particularly welcome was the program's new ability to automatically download images for nearly all the objects in an observing list.

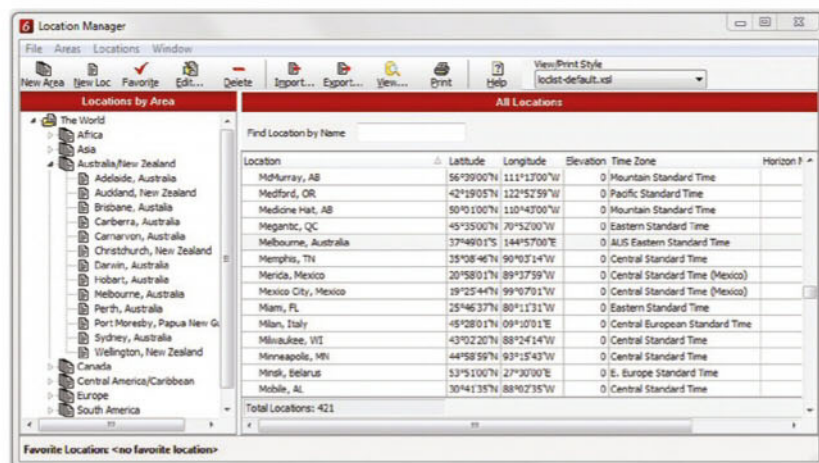
Getting started

If you're new to planning programs, your first look at *DSP 6* may be a little daunting. What comes up on your display is a blank screen with a fairly standard Windows pull-down menu across the top. Beneath it is an icon bar, and below that are additional menus with a clear astronomical bent: Instrument, Camera, Eyepiece, Filter, Barlow/Compressor and Observer.

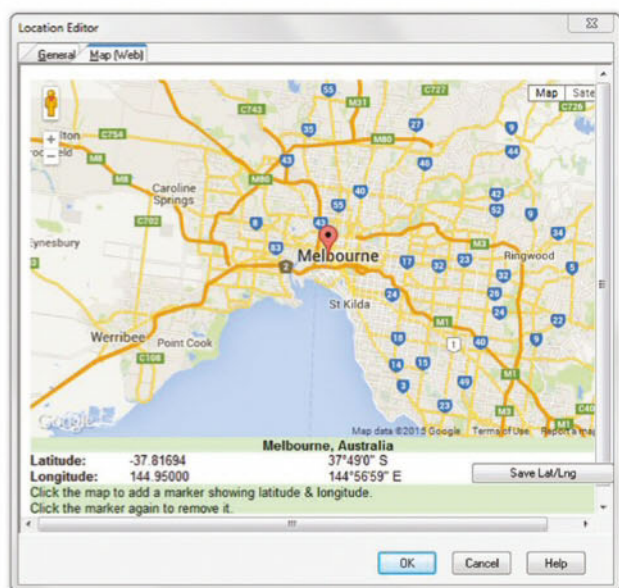
So where to start? As with most astronomy programs, begin by entering the particulars of your location and equipment. Most important is location, which is opened by selecting the Options > Location Manager. A new window opens, with two primary categories: Location By Area at left, and All Locations at right.

Once you choose your city, a window will appear with the location's particulars filled in. Make sure everything is correct — latitude, longitude, time zone — make any changes if needed, then click OK and you're done. If your city is not on the list, you can select 'New Location' and enter the particulars of your site manually.

Next up is inputting your equipment. Select Equipment/Observer > Instrument Browser from



Like all planning programs, the first thing you'll need to do is input your location and your equipment. You can select your city from an extensive built-in list, or find your area in the Map (Web) tab, which is a link to Google Maps.

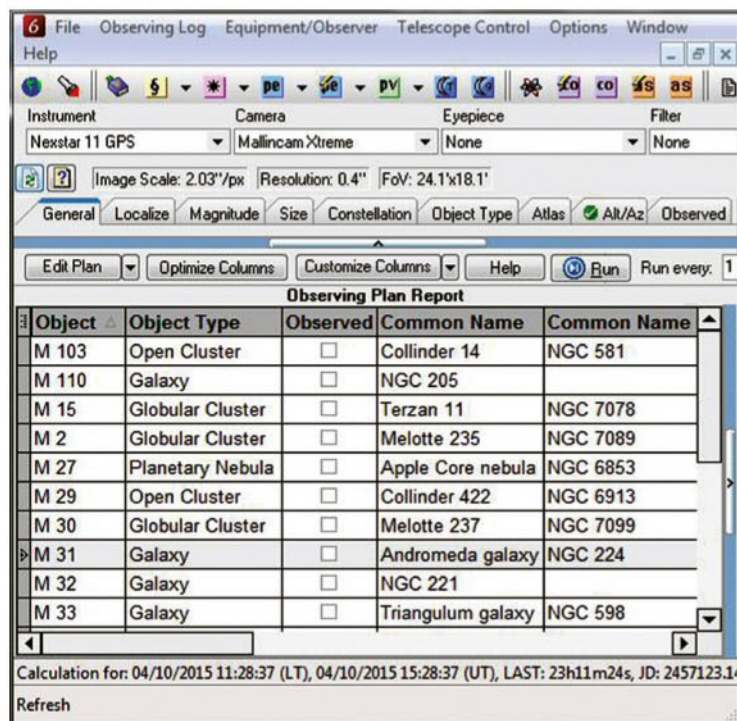
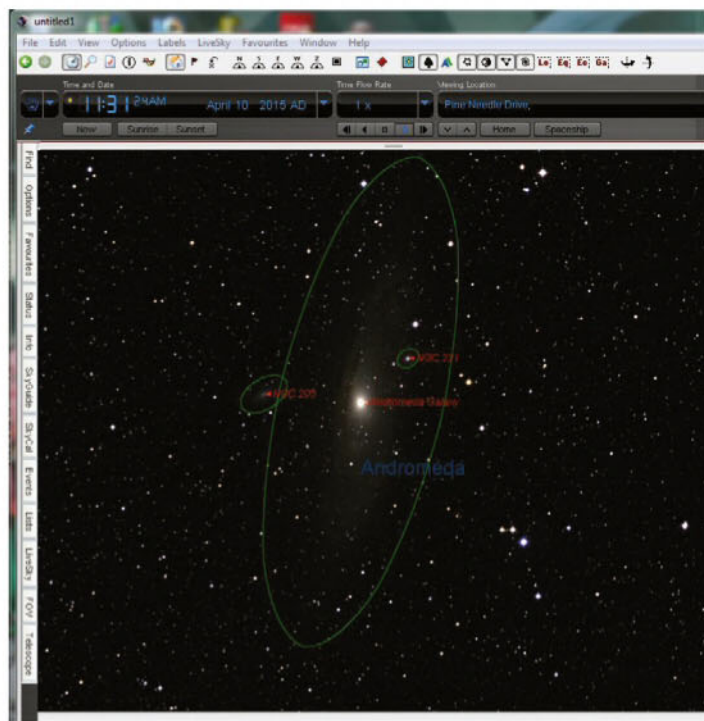


the pull-down menu at the top of the screen. Now click the 'New' button at top left of this new window and key in your scope's statistics. Do the same for other gear you're using in each category. The program requires this data because *DSP 6* is a planning and logging program. Entering this

information means *DSP* can insert it in log entries automatically, meaning less typing in the field.

Your basic setup is complete, so it's time to get to know the program. The main purpose of *DSP 6* is to help you build observing lists by choosing objects from its database. There's

The program offers you many options to narrow down your observing list, with options to ignore objects that never rise from your site, or target only objects within a designated constellation. Additionally, *DSP 6* can download a Digitised Sky Survey image of nearly any deep sky object you want to observe.



Deep-Sky Planner 6 enables you to link to most popular planetarium programs to create finder charts. Simply select your preferred software in the pull-down menu **Options > Star Chart Programs**.

no lack of objects to choose among here — *DSP 6* includes more than 1.25 million entries in its deep sky and stellar databases: 841,000 star clusters, galaxies and nebulae, and 411,000 stars.

Before making an observing list, note that Knightware provides a sizable library of Observing Plans on its website. Nearly 350 plans are available, encompassing everything from binocular objects to galaxy

clusters. You can access and download any of these pre-generated observing plans by selecting **Help > Community Page** (Online).

If none of the plans in the library fit your specific needs, it's easy to make your own. Let's assume you're after deep sky objects (*DSP 6* also includes a large selection of Solar System objects including asteroids and comets). Click the spiral galaxy icon on the toolbar: this opens the obliquely named but powerful 'Deep Sky catalogue search documents' search engine.

The first step is choosing the deep sky catalogues you want to search. Click the **General** tab in the search window, which displays a list of the program's catalogues. For example, I highlighted *NGC: Revised New General Catalogue*. Clicking the **Search** button now will retrieve all the NGCs, but I certainly didn't want 7,840 objects in my plan. Fortunately, you can simply use the other tabs to help narrow the search.

Given my experiences with other planners, I expected to wait awhile after clicking the **Search** button, but in just a couple of seconds *DSP 6* produced a comprehensive list of all the 10th-magnitude-and-brighter NGC objects in a spreadsheet

The program incorporates the ASCOM universal telescope protocol, so it will communicate with most computerised scopes and mounts.

containing plenty of information about each. These results can then be ordered in any way you prefer by clicking the title above each column.

To turn these search results into an observing plan, select **New > Observing Plan** from the pull-down menu. You then populate your Observing Plan by dragging and dropping single or multiple objects from the search results window.

Highlight multiple objects by holding the shift key while clicking objects in the search window before dragging them into the Observing Plan window.

Deep-Sky Planner 6 also allows you to import plain text (ASCII) files of objects. The program took a little

SYSTEM REQUIREMENTS

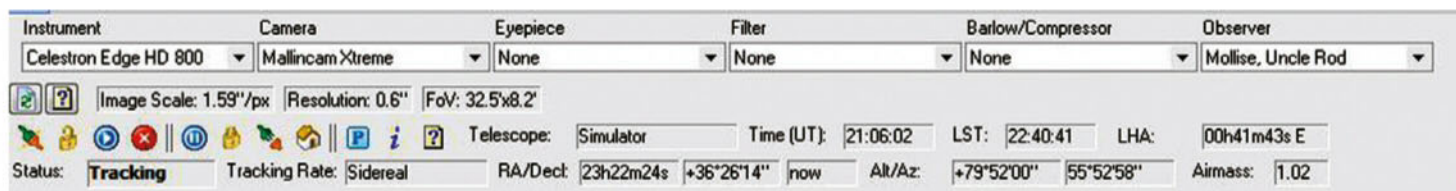
PC with Intel Pentium processor (or equivalent), 1 GHz or faster.

32- or 64-bit edition of **Windows (XP or later)** including the latest updates from Microsoft

128 MB RAM for **Windows XP**, 512 MB RAM for **Windows Vista**, 1 GB RAM if operating 32-bit **Windows 7 or 8**, 2 GB RAM if running 64-bit **Windows 7 or 8**.

Installation requires about 366 MB of hard disk space.

XGA (1024 x 768) or better graphics, **Windows XP or Vista**, DirectX 9 graphics device with WDDM 1.0 or higher driver on **Windows 7 or 8**.



over a minute to import my list of 700 objects and convert them into an Observing Plan.

With my completed plan on screen, I took a look at the program's other options. One button on the Observing Plan window titled 'Run' puzzled me at first, though it turned out to be one of the program's most useful features. In the tabs at the top of this window, the Alt/Az tab allows you to specify observing altitude parameters to filter out objects that are too low to observe, or prevent an alt/az mounted Go To scope from pointing at the zenith. Clicking the Run button updates your plan to show only objects within these parameters, and adds new objects as they meet these criteria. 'Run' is a great feature, but I wish the button were more clearly labelled, perhaps as 'Update.'

The Run feature can be used to filter objects based on magnitude, observed/

not observed status. It can also be set to specify how often your spreadsheet will be automatically updated using the Auto button.

At the telescope

Now that you've got a plan, what do you do with it? You could print it out and carry the hard copy into the field, though *Deep-Sky Planner 6* is well-suited to running on a computer at your telescope. The program, which includes a useful red-screen, night-vision mode, is as useful for non-computerised Dobsonian telescopes as it is for Go To rigs, but it is a joy to use with a Go To-enabled telescope.

The program incorporates the ASCOM universal telescope protocol, so it will communicate with most computerised telescopes and mounts. Simply connect your mount to your computer and find your model in the Telescope Control menu, and you can issue go-to commands by right-clicking a target object in the Plan and selecting 'Slew To.' This works well, though it would be helpful if the button were located on the main screen.

I often find it helpful to look at the photo of an object I am hunting, and *DSP 6* makes that easy. Click the 'Get DSS Images' button on the right side of the Observing Plan window, and you can retrieve an image for the highlighted object. 'DSS' refers to the Digitised Sky Survey, the online version of the Palomar Observatory Sky Surveys. You can download DSS pictures for objects individually or in batches. The images are then saved on the hard drive for future use and can be viewed at any time.

Sometimes a picture isn't enough; sometimes I need a star chart. Rather than generating its own maps, *DSP 6* works with third-party planetarium software, including TheSkyX, Starry Night and Cartes du Ciel. Select your planetarium program in the Options menu, and *DSP 6* will link to it for your charting needs. Right-click an

Deep-Sky Planner 6 can also control most Go To telescopes, enabling you to slew to your next target, though it isn't immediately apparent how to do this. Right-clicking on an object in your Observing List opens a dialog box that includes the 'Slew To' function halfway down the screen.

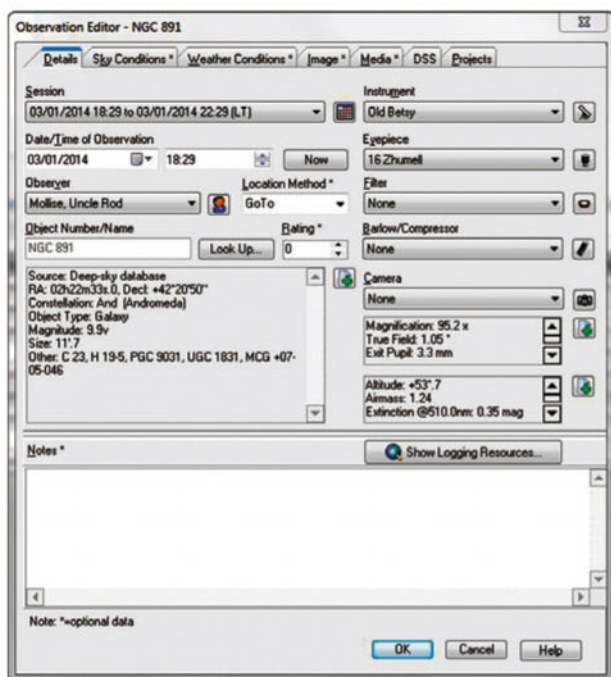
object in your Observing Plan, select Show Chart, and *DSP 6* will minimise and the planetarium program will open, centred on the target.

After you've taken a good, long look at an object, it's time to record your observation. To do so, select the 'Observations' tab in the same right-hand pane you see the DSS image. Click 'Add Observation' and the program's logbook will open. Most information, including date, time and the telescope and other currently selected equipment is already filled in for you. All you have to do is record your impressions.

I won't hesitate to say *Deep-Sky Planner 6* was one of the most professional, best-working astronomy programs I'd used in a while, but that doesn't mean it was perfect — what software is? It would be nice if the program would load my last Observing Plan at startup. I'd also like to be able to set an object's status in the Plan spreadsheet to 'Observed' without having to make a log entry. Finally, a couple functions weren't clearly named — fortunately, the excellent help menu always made their purposes clear.

Using *Deep-Sky Planner 6*, I'm seeing more objects, and — thanks to being prompted to make descriptive log entries — I'm seeing more details than ever in those objects. I won't say *Deep-Sky Planner 6* has changed my life, but it's definitely improved amateur astronomy for me, and that is a big part of my life. ♦

Contributing editor Rod Mollise writes an astronomical blog at uncle-rods.blogspot.com



Once you've successfully observed a target, click on the Observations tab at the far right of your Observing List window to enter any notes on the object.



Nordic nights

Intrepid Aussie amateurs hunt an eclipse and aurorae at the other end of the planet.

BY MELISSA HULBERT

It was four years ago that Cathi Humphrey-Hood and I started planning for the March 20, 2015 total solar eclipse, which would be visible from the far north of the planet. After first deciding to go to the Faeroe Islands for witness it, further research indicated there was a marginally (and I mean minutely marginal) better chance of good weather in Svalbard, so we opted for the latter archipelago, well inside the Arctic Circle. Joining us on the trip were David and Wendy Bevan, Rob Lucas, Helen Robinson and Cathi's children Elswyth and Aengus.

Of course a visit to this part of the world in March meant that aurora hunting was also going to feature, so we planned a trip to encompass the Norwegian mainland as well as Svalbard.

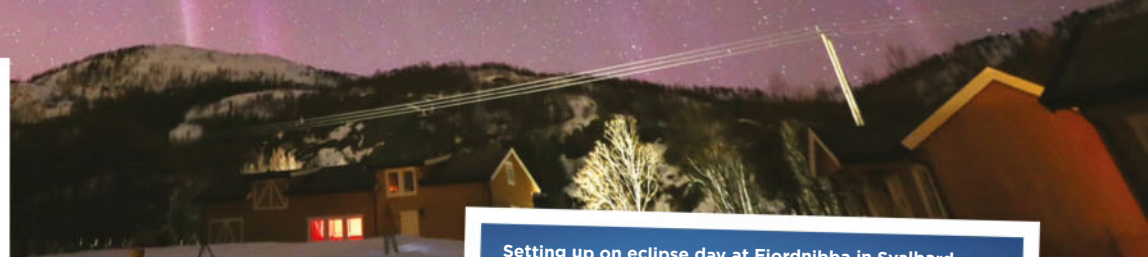
After a few days in Oslo we headed to Alta, but unfortunately cloudy nights and snow storms prevented any aurora viewing. We arrived in Tromsø to find cloudy skies but upon enquiry were told that Saturday night (two nights away — March 14) would be the best chance. We chose to go with Tromsø Safari for our first night of aurora chasing as they impressed us with their knowledge and they were even prepared to take you to the Finnish border so that you could see the aurorae. We were not disappointed.

We arrived at one of their base camps overlooking the fjords and waited. About 9pm the soft glow of the

aurora started and over the next few hours intensified. Dancing curtains of light gently swirled and moved above us and not only were we treated to the usual green and often red but also purple and yellow.

It was rather cool during the night (about -10 degrees) however the company had two large fire pits and a hut with warm drinks and snacks to keep everyone going. I have to say I only ventured inside towards the end of the evening as the aurora died down, as I couldn't pull myself away from the wonderful show happening above and around me. I did hear that some people on the tour were disappointed as they expected to see the wonderful colours you see in photographs. For us this wasn't the case; perhaps as experienced observers we were used to the fact that the colours seen with the eye tend to be more greyish. That said, we were still able to see the green hues as well as some red and turquoise.

The following night was unfortunately cloudy, but the 16th was clear and we joined friends Joe Cali, Matt Poulton and Bengt Alfredsson on an aurora chase to Kvaløya, another Norwegian island. Although slightly fainter than on the



Setting up on eclipse day at Fjordnibba in Svalbard.

14th, the purple and yellow in the aurorae were stronger and, along with the usual green and red, we also saw a deep turquoise blue from time to time.

The next day saw us heading to Svalbard. Approaching Longyearbyen airport we saw lots of sheet ice over the ocean and small icebergs — we were definitely well inside the Arctic Circle. Longyearbyen is a small frontier town in the Svalbard archipelago and I must say I wondered what the locals thought when thousands of astronomers and umbraphiles descended upon them for a week in March. We had arrived a few days early and, after two days of cloud, the 19th dawned bright and clear, and in fact was only the third day the Sun had been seen since it returned to the sky on

Astro Calendar

Queensland Astrofest

August 7-16
Annual star party
qldastrofest.org.au

National Science Week

August 15-23
Lots of public astronomy activities held around Australia
scienceweek.net.au

World Record Stargazing

August 21
Mt Stromlo Observatory leads two world-record stargazing efforts
rsaa.anu.edu.au/world-record-stargazing

StarFest 2015

October 2-4
Held at Coonabarabran, home to Siding Spring Observatory, there'll be three days of activities during the Festival of the Stars
starfest.org.au

Siding Spring Open Day 2015

October 3
Australia's largest optical observatory throws open its doors to the public
starfest.org.au

Border Stargaze

October 8-11
Amateur astronomy star party near Albury on the NSW-Vic border
asaw.org.au/bsg

VicSouth Desert Spring Star Party

November 6-9
Annual star party hosted by the astro societies of Victoria and South Australia
vicsouth.info

National Australian Convention of Amateur Astronomers

March 25-28, 2016
Held every second year, the NACAA is Australia's premier get together for amateur astronomers to discuss research projects and the latest technologies. In 2016 it will be hosted by the Sutherland Astronomical Society in Sydney.
nacaa.org.au

WHAT'S GOING ON?

Do you have an event or activity coming up? Email us at editor@skyandtelescope.com.au.



The diamond ring effect.

February 24. We were all hoping that this weather would hold for the eclipse the following day – surely Mother Nature wouldn't taunt us so?

Eclipse day dawned cold (-24 degrees), bright and clear and we headed off early on snowmobiles to a remote area away from Longyearbyen. High on the mountain at Fjordnibba, overlooking Tempelfjorden, was the perfect place from which to witness the eclipse.

Although it took some time to reach our observing destination and we missed the very start of the eclipse, we were very pleased with the choice of site. The partial phases passed quickly and as the diamond ring approached, amazing shadow bands rippled like bands of fairy lights across the snowy plain in front of

us — an incredible sight.

Then, what we had come all this way for – totality! This eclipse appeared mostly pink with soft blue undertones to the eye and the soft glow around the surrounding hills was spectacular. Totality once again passed all too quickly and the second diamond ring signalled the end and a return to the partial phases.

To be in such an amazing, remote and wonderful place with crystal clear skies and watching the twilight at totality lighting the mountains, made this one of the most memorable eclipses I have seen.

The aurora nights and the eclipse day were the highlights of our Nordic adventure, and an experience that my friends and we will never forget. ♦

10 & 5 Years Ago



August 2005

First pictures of exoplanets?

On April 27, 2004, a European/American imaged the dim brown dwarf 2M 1207, revealing an extremely faint, red blip just 0.78 arcsecond from it. "We understood essentially immediately that we had a very strong exoplanet candidate," says Ben M. Zuckerman (UCLA). In January 2005 Glenn H. Schneider (U.

Arizona) presented Hubble observations that essentially confirmed that the star and its companion have common motion across the sky, a very strong indication that they are gravitationally bound.



Aug/Sep 2010

Stars are not born equal

With masses tens of times that of the Sun and with light outputs millions of times higher, the largest stars hold the power of life and death. They destroy protoplanetary disks and trigger the birth of other stars. And after their brief but flamboyant lives, they die in titanic supernova explosions. Because the most massive stars

produce the greatest impact, the record holders constitute an astronomical 'holy grail'. So if you want to understand the universe, you need to understand these huge objects.



Astrophotos from our readers



▲ SCORPIUS RISING

Gary Plummer

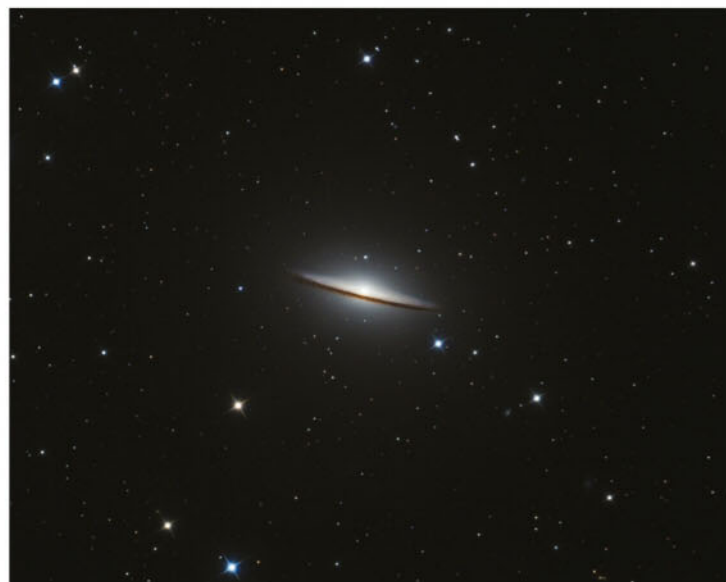
There's nothing quite like the sight of the Milky Way rising over the horizon at a dark sky location, such as West Barwon Dam, near Forrest, Victoria, from where Gary made this eight-image panorama. He used a Sony A99 camera and Samyang 24mm lens; each exposure was 20 seconds at f/1.4, 3200 ISO.



▲ HOT FILAMENT

Teale Bristra

This was how the Sun looked on February 9 this year, with a huge filament spanning its surface. Teale used a Lunt LS50THa/B600 H-alpha telescope and a ZWO ASI 120MM-S monochrome camera. From about 2,000 frames he stacked the best 150 with Registax; colour was added later using Photoshop.



▲ SOMBRERO GALAXY

Paul Haese

The Sombrero galaxy, or M104, is 28 million light-years from Earth. Paul snapped it using an STXL-11002 camera and GSO RC12 telescope. Software used was MaximDL, Focusmax, Pinpoint, CCDautopilot 5, CCD stack and Photoshop CS6.



▲ ECLIPSE PROGRESSION

Will Godward

Skies were clear in South Australia for the lunar eclipse earlier this year. Will used a Canon 5D mk2 camera, Canon 400mm 2.8 lens and a Skywatcher EQ6 pro.

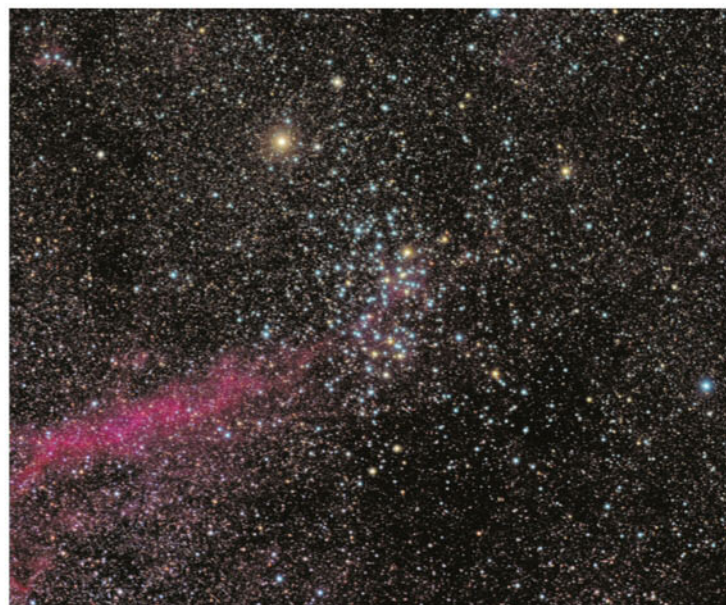
Exposures were at f/5.6, between 1 second and 1/500th-second at ISO 400-800.



◀ EMU RISING

Katrina Edmunds

The emu in the Milky Way was captured from Ben Lomond in Tassie. Katrina used a Canon EOS 60 Da camera with a Canon 10-22mm lens, set at 10mm f/8. Exposure time was 10 minutes at ISO 1600.



▶ WISHING WELL

Barry Brook

The famous southern open star cluster NGC 3532, sometimes known as the 'Wishing Well', is about 1,300 light-years away in the direction of Carina and covers an area of sky around twice that of the full Moon. Barry used an Orion ED80T CF refractor at f/4.8 on a Skywatcher AZ-EQ6 GT mount, a QHY22 monochrome camera and a total of 5.5 hours exposure.

HOW TO SUBMIT YOUR IMAGES

Images should be sent electronically. Please email your contributions@skyandtelescope.com.au and provide full details of all images, eg. date and time taken; telescope and/or lens used; mount; imaging equipment type and model; filter (if used); exposure or integration time; and any software processing employed. If you have a contributed image published in *Australian Sky & Telescope*, you'll receive a 3-issue subscription or renewal to the magazine.

AUSTRALIAN SKY & TELESCOPE

Market Place

Astro Shop .com.au

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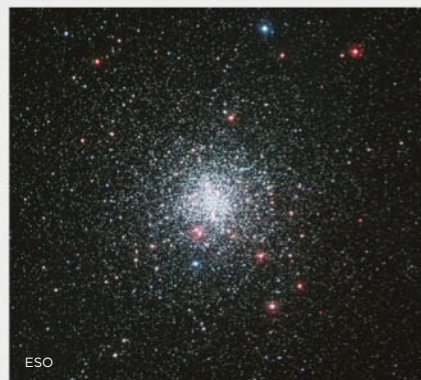
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Why astrology ‘works’

People pay attention to astrology for a good reason. Astronomers should know it.

Did that get your attention? As an editor who’s not shy about explaining pseudoscience to its believers’ faces, and ranting about ‘pathetic woo’ (skeptdic.com/woowoo.html) behind their backs, I’m treated with a certain caution by the three professional astrologers among my friends and acquaintances.

By ‘professional’ I mean they’ve cast horoscopes for pay. They apparently give good value; customers come back. They’ve learned better than to try to give me lame physics woo, such as the stuff you’ll hear about our bodies being mostly water and celestial objects raising tides within us. They’ve been well instructed that each of the millions of pebbles in your yard has a greater tidal effect on your body (water or otherwise) than Jupiter, Mars or Venus do. (Here are the maths: is.gd/pebbletides.)

And they know I’ll also tell them about the many experiments showing

that you can take the best professional horoscopes, shuffle them up, and people will deem a random one just as amazingly insightful as their own. Nor can people pick their own reading from a selection more often than chance. The planets have nothing to do with it.

But that’s not the point. If you want to get through to your believing sister-in-law or your uncle in Woop Woop, the way to do it is not to argue physics or astronomy, but to explain why astrology works.

I tell this with my own story. When I was in primary school, I practiced a form of divination that you could call bazookamancy. Back then, Bazooka Joe bubble gum was popular. It came wrapped in a little comic strip about Bazooka Joe and his gang. The wrappers were on the ground wherever kids littered. The custom was, when you saw one, you stopped and asked it a question. Then you picked it up and read it. The comic was a parable that answered your question. Often you had to look mighty hard to find your answer. But if you looked hard enough, it was always there.

Even at age 10, I explain, I was smart enough to know that cosmic forces had not placed the comic in my path. It was there because some kid threw it away. But it confronted me with a *random reading*, a random input from outside



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of myself, just like a horoscope: an assertion about me and my situation. It forced me to see things from an outside perspective. And that could be a dash of cold water.

Two Bazooka Joe revelations that I remember: a friend was teasing me not because he wanted my attention as my mother said, but because he *actually disliked me*. It was a wake-up I needed. The other: I shouldn’t join a group that was planning to get a ladder and climb into a second-story window after school, because trouble was brewing. As it was. It took a prompt for me to grasp that.

I’ve described my practice of bazookamancy to two of my astrologer friends. Each of them lit up and said, “You’ve got it!” So at some level they know it isn’t about the planets, not if one form of divination is as good as another. Any reading or fluke or chance — any *metaphor looking for its referent* — will serve your uncle in Woop Woop just as well.

With that out of the way, he may be more willing to talk about how the planets and tides really work — and maybe how humans work too. ♦

Alan MacRobert, an astronomy editor for 33 years, happily participates in solstice drum circles, visionings in clouds and other forms of woo that stay in their place.

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